

Summer Planetaries!

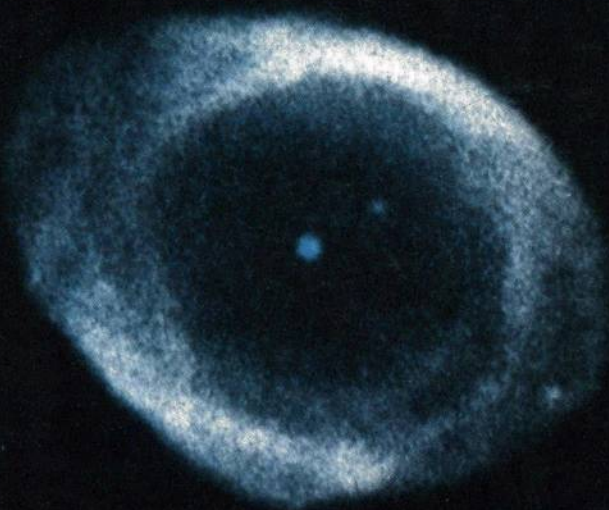
DEEP SKY

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*Galaxies Around the
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*255 Planetary
Nebulae in the
Summer Sky*

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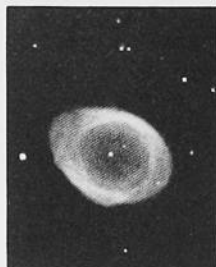
The Central Stars of Planetary Nebulae

Astronomy's Latest Research News

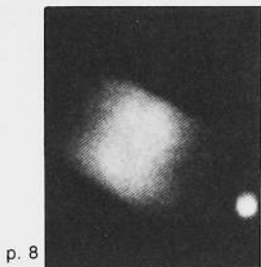


Planetary nebulae come in all shapes and sizes. Top left: The Dumbbell Nebula in Vulpecula. Photo by Raymond T. Martin. Top right: The Saturn Nebula in Aquarius. Photo by Dan Marcus and Bill Smith. Center right: NGC 7662 in Andromeda. Photo by Jack Metcalfe. Bottom right: NGC 6905 in Delphinus. Photo by Jack B. Marling.

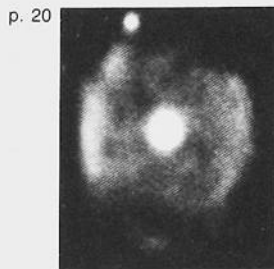




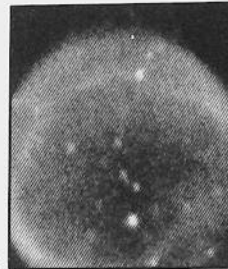
Cover: The Ring Nebula, M57, photographed by Jack B. Marling using the 24-inch f/15 Cassegrain telescope on Mauna Kea, Hawaii.



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8 Summer's Multitude of Planetaries

by Jack B. Marling

Summer is the time to observe planetary nebulae. The rich Milky Way stretches overhead from Cassiopeia in the north to Centaurus in the south, all along the way speckled by ancient remnants of dying stars that have puffed off their shells. This article provides tips on observing and photographing planetaries, gives extensive notes by California observers Jack Marling, Steve Gottlieb, Tokuo Nokamoto, and Dana Patchick, and lists fundamental data for 255 planetaries in the summer sky.

20 The Central Stars of Planetary Nebulae

by David Kratz

When a star less than 8 solar masses runs out of nuclear fuel to burn, it swells into a red giant. Shortly thereafter, the star slowly dies by puffing out successive layers of material into space and eventually becomes a planetary nebula. After expelling enough material to weigh in at only about 0.6 solar mass, the progenitor star becomes a white dwarf. This article explains the lifetimes of planetary nebulae stars, which last only about 50,000 years, and tells you how to observe many of them.

26 Observing Planetaries from the City

by Alister Ling

Because most planetary nebulae have rather high surface brightnesses, they aren't as critically affected as galaxies or emission nebulae by slightly imperfect observing conditions. This pleasant fact means that many city-bound observers can spot huge numbers of planetaries without traveling to a dark-sky site. In this article, Canadian expert observer Alister Ling describes his observations of planetaries from Montreal.

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Inside View

Planetaries for Everyone

As demonstrated by the first three articles in this issue, planetary nebulae come in a wide variety of shapes, sizes, and brightnesses. This accounts for their immense popularity as a class of deep-sky objects, and explains why observers with 2-inch telescopes and those with 20-inch telescopes seem to be equally fascinated by them.

With this in mind, we're happy to provide this special planetary nebula issue. Jack Marling's article, beginning on page 8, lists data for 255 planetary nebulae in the summer and early fall skies, including many magnitudes Jack calculated himself. Also included are observational notes by the experienced observers Steve Gottlieb, Tokuo Nokamoto, and Dana Patchick. It is an important contribution to the literature on observing summer planetaries.

In the issue's second part, David Kratz of the State University of New York at Stony Brook presents a

detailed account of planetary nebulae central stars, including an observational list. Central stars run the gamut from invisible to very bright; in fact there are some planetaries wherein the central star only is visible, and not the nebulosity! The information in Dave's article should make finding many of these stars a pleasure.

Canadian observer Alister Ling contributes the final part of this trilogy — a piece on observing planetaries from cities. Certainly many of us are bound to light polluted areas in pursuing careers, and travelling outward to a really dark site takes some effort. Luckily because they are relatively bright and small, many planetaries have very high surface brightness disks. This enables you to view them under imperfect conditions without losing a great amount of detail. Alister's observations of planetaries from Montreal serve as a guide as to what can be seen from a modern urban area.

Other features round out the issue:

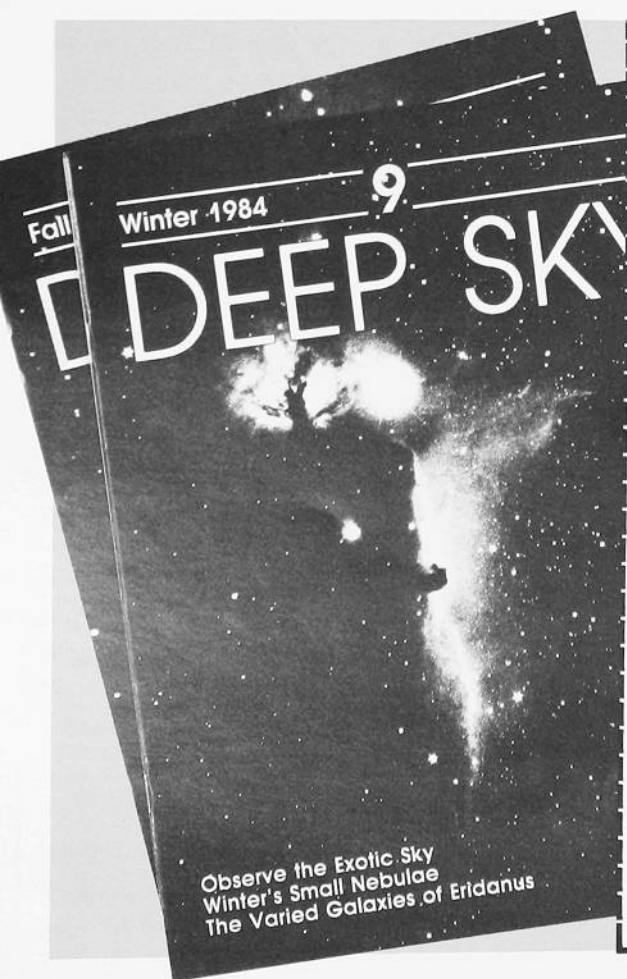
"Deep Sky Sketchbook" this time features observations made by Tom Sarna of Downers Grove, Illinois. Tom is an avid deep-sky observer and the author of the *Sarna Deep-Sky Atlas*, a collection of finder charts for observers with large telescopes. In our review column Brian Skiff of Lowell Observatory explains the *Southern Galaxy Catalogue*, an important contribution to the data on southern galaxies by Harold Corwin of the University of Texas. And the usual columns on doubles, variables, and news items from the world of astronomy round out this edition of DSM.

I enjoyed meeting many readers at the Texas Star Party in Fort Davis last May, and look forward to seeing more of you at Stellafane this August in Springfield, Vermont. Clear skies!

Yours truly,



Dave Eicher
Editor



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Letters to DSM

Give Us Finder Charts!

Dear Sir / Thanks for a wonderful magazine! I am a 23-year-old amateur astronomer from Sweden. My observations are made with a 4.5-inch f/8 reflector, a small instrument in these days of Dobsonians. The views of most objects are therefore anything but impressive, but to me it has the advantage that in a reasonable amount of time you can see all of the objects visible with the telescope. So far I have seen approximately 400 objects — but since I have not observed many galaxies in Virgo or Ursa Major I expect the number to eventually rise well above 1000.

My favorite objects are planetaries and I was therefore very pleased with the spring 1984 issue, *Deep Sky* #6. The one thing I "criticize" is that there were no finder charts (or even better, large scale photos) showing the small and faint nebulae. The well-known objects are easy to find and frequently are photographed. Since I have observed 50 planetaries it is becoming increasingly difficult to find "stellar" planetaries often lost in a rich background of stars.

Something that fascinates me is that some planetaries within the reach of amateur instruments were unknown to professional astronomers until relatively recently. An example is Henize 1-3 in Vulpecula, a fairly bright planetary that appears stellar to me. An object I'm uncertain about is NGC 1985, variously described as a planetary or an emission nebula. Although it's difficult to see, I pinpointed it on a photograph and used that to spot it in the 4.5-inch at 100x. I'm unsure whether I'm seeing the 13.3 magnitude central star or the 1' x 1' nebula. I saw it only with averted vision and couldn't judge its size accurately — can you help me?

I'm surprised at the description of NGC 404 in *Deep Sky* #4. Although my telescope has rather poor optics, the galaxy is easy to see even when Beta (β) Andromedae is in the field as well. At 50x they form a striking pair that I observe almost every time I go outside. I also saw it in a 2.4-inch telescope, although in this instrument the star is more disturbing and the galaxy appears as only a faint smudge.

The two distant companions to the Andromeda Galaxy, NGC 147 and NGC 185, seem to change appearances drastically in different telescopes. Some observers think NGC 147 is brighter; others NGC 185. In my 4.5-inch scope NGC 185 is always the easiest, and is often better looking than NGC 205. On

the other hand, NGC 147 is very difficult even with averted vision.

The faintest galaxies I've observed so far are NGC 2968 in Leo, NGC 3158 in Leo Minor, and NGC 4632 in Virgo.

Once again thank you for a wonderful magazine!

Soren Jensen
Lovnas Bjurtjam
68800 Storfors, Sweden

Mr. Jensen / Thank you for your letter — you seem to be enjoying your observing program, and you're quite correct that quite a lot can be observed with a small instrument.

Addressing your questions: We will certainly publish large scale finder charts for stellar planetary nebulae when they are available. The only such charts I know of on a more-or-less standard system are those in the Perek/Kohoutek Catalogue of Galactic Planetary Nebulae, now out of print. We'll see what we can do about coming up with such finder charts in a future issue of Deep Sky.

NGC 1985 is not a planetary nebula nor a normal emission nebula but rather a nova remnant — the expanded remains of T Aurigae, which went nova in 1891. The remnant is very faint and measures, as you thought, about an arcminute across.

Fortunately both NGC 147 and NGC 185 have been thoroughly studied by professionals over the past few decades. They have been photometered extensively, and NGC 185 is definitely brighter both in total brightness and in surface brightness. NGC 185's total V magnitude is 9.17 and its mean surface brightness 15.2 magnitudes per square arcminute, while NGC 147's V magnitude is 9.46 and its mean surface brightness 15.4. They're close, but NGC 185 is the brighter. — DJE.

More on M57's Central Star

Dear Dave / In response to Mr. Smith's letter about M57's central star in *Deep Sky* 13: as a builder and user of many types of telescopes, I can honestly say that I have seen the central star in M57 only once. My observation was shared and confirmed by Gene Cross while testing a 20-inch reflector. The details were: (1) M57 was directly overhead, (2) a first quarter Moon was 20° above the western horizon, (3) the telescope was a 20-inch f/5 Newtonian built for and owned by John Liptak of New York, and (4) the magnification used was 250x. The sky was fairly bright, but this may

have suppressed the internal nebulosity and allowed the star to be seen by direct vision. My 12-inch f/5 AstroMak shows many stars around the periphery of M57 yet no central star, despite revealing other stars of magnitudes 15.2 and 15.3.

Jim Riffle, President
Astro Works Corp.
175 Piedra Loop
Los Alamos, NM 87544

Kudos for Schur

Dear Dave / Chris Schur's closing paragraph in "Observing Small Nebulae — Part II" (*Deep Sky* 11) was one of the most profound statements in your magazine — it was truly inspired! Every deep-sky observer should read his words and take them to heart. Of the three critical observing elements — observer, sky, and instrument — there is no doubt that instrument is the least important. Patience, perseverance, and love of the sky are the most important attributes an observer can possess, and they are necessary in achieving the greatest possible fulfillment from observing.

Patrick W. Drigans
1280 Hathaway Lane
Fridley, MN 55432

Wanted: Cometary Magnitude Estimates

Dear Sir / I read with interest the accounts in *Deep Sky* 13 by J. Marling (pages 4 and 30) and S. Gottlieb (page 4) concerning the observation of faint deep-sky objects with moderate-size telescopes. I conduct research into the photometric behavior of comets and publish large quantities of total visual magnitude estimates of comets in the *International Comet Quarterly* (ICQ). Comets have one thing in common with deep-sky objects such as galaxies, faint globular clusters, and planetary nebulae: they are similar in appearance and quite often in the distribution of surface brightness.

I am encouraging observers to try observing comets (and to make good magnitude estimates of the integrated coma brightness by defocusing stars having good V magnitudes) that are fainter than total visual magnitude 12. Very little data is available on comets fainter than magnitude 12, so every bit of good observational data contributes a great deal to the study of the nature of comets. I am also interested in observational problems encountered by visual observers when they look at comets. I have been working on an in-depth study

of the nature of the human eye and its response at low light levels. Keith Bowen of the University of Colorado at Boulder and I are recruiting experienced observers for such a study; if readers are interested in participating, they can write to me for placement on our news mailing list.

I am particularly interested in receiving information from your readers about their observations of deep-sky objects fainter than magnitude 14, with reference to the type of instrument used for the observations. I'd like to know the smallest instrument needed to definitely detect certain objects along with reliable estimates of magnitudes for given deep-sky objects. If you're interested in participating but don't make estimates yourself, note the published source for magnitudes; if you do make estimates, describe how you did so and provide the name of the star catalogue you used.

There do indeed seem to be differences in spectral response from one human eye to another, and this causes a difference in detection of given objects from observer to observer. It seems that little research or study has been done in this area. A place for observers to start is with the charts published by Edgar Everhart in *Sky and Telescope* (67: 28-30, Jan. 1984), which will help determine the faintest stars your telescope can show on a clear, dark night. (Note that the finder chart for Sa 51 in Everhart's article is wrong, however.) Good magnitude estimates for extended objects can be obtained by either (1) defocusing the comparison star and the deep-sky object until they are just about the same size, or (2) defocusing the comparison star to the size of the in-focus deep-sky object.

Daniel W.E. Green, Editor
International Comet Quarterly
 Smithsonian Astrophysical Observatory
 60 Garden Street
 Cambridge, MA 02138

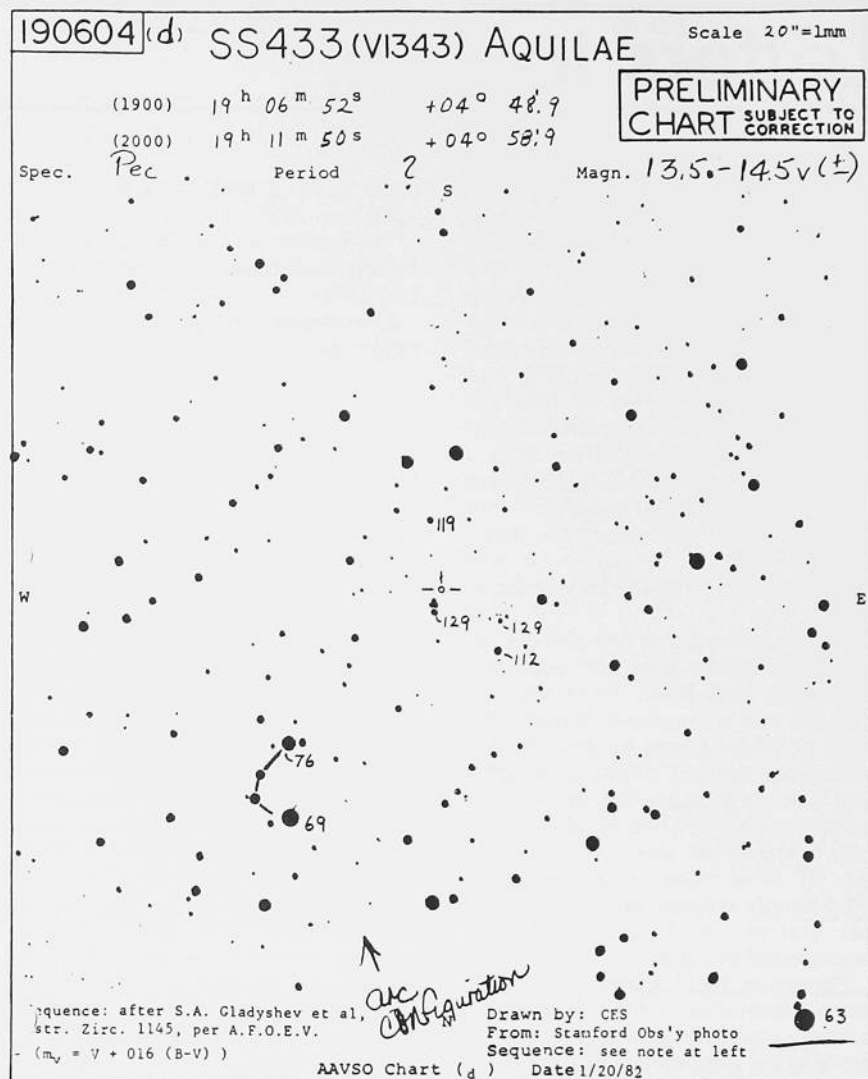
AAVSO Charts for SS-433

Dear Dave / Regarding the confusion over locating SS-433: I've been observing this unique object for over three years and am enclosing a preliminary chart from the AAVSO which should make finding it easy. The magnitude 6.9 and 7.6 stars are plotted on Tirion's *Sky Atlas 2000.0*. Happy Hunting!

David D. Weier
 205 Cameo Lane
 Madison, WI 53714

Why Bother With Double Stars?

Dear Mr. Eicher / In *Deep Sky 13*, Glenn F. Chaple made the following statement: "Halley's Comet is visiting the night sky for the first time in three-



This preliminary finder chart for SS-433 should satisfy readers who want to hunt down this mysterious object. Reproduced courtesy Janet A. Mattei, director, American Association of Variable Star Observers. For comparison see the photograph on page 7.

quarters of a century, and I wonder how many telescope owners are going to bother with a bunch of double stars."

Let me state emphatically that I will! For those of us interested in double stars, it is difficult to find articles — much less columns — devoted to double star observing. I own an 8-inch refractor with an R.E. Brandt lens and live in a location where moderate light pollution restricts me to viewing the Moon, planets, and double stars. From this location, I've observed Halley's Comet approximately 24 times and have made 14 drawings of it. Despite these observations, I must admit to a great interest in observing double stars. The variety of these most interesting objects is almost endless. There are wide variations in both magnitudes and separations of these pairs of stars, and

also subtle variations in contrast of colors.

A nice facet of double star observing is my recent interest in the history of astronomy. I feel a strong connection with observers of the 19th century when I observe these objects. Admiral Smyth's books — *Cycle of Celestial Objects*, *Speculum Hartwellianum*, and *Colours of Double Stars* — give me endless hours of enjoyment as I compare my visual impressions and color estimates with his. *Celestial Objects for Common Telescopes* by Webb is, of course, a classic. *Pleasures of the Telescope* by Garrett Serviss contains beautiful descriptions of double stars made with 3-inch, 4-inch, and 5-inch refractors. I enjoy reading about such prominent double star observers as Dawes and Burnham because of the

aperture range of the instruments they used. I collect astronomy books, particularly of the 19th century, for the wonderful visual descriptions they contain.

A few very nice double stars that I have recently observed include Epsilon (ϵ) Equuleus, a beautiful object at low power that consists of light yellow and blue stars and at high power transforms into a triple star. The light yellow star (mags. 6.0 and 6.3; sep. 1.1") splits rather easily at high power. On October 24, 1985, I observed 4 Aquarii. The separation is variously listed as 1.1" or 0.6" Gamma (γ) Andromedae is a beautiful yellow and light blue (with a hint of green) double star. When I recently examined component B under high power, the star appeared definitely elongated, although not cleanly split. My estimate of the p.a. was 100° to 110° . When I observed it in November at 300x, 7 Tauri (having a separation of 0.6") appeared as a figure 8 and almost, but not quite, split.

In conclusion, let me thank Mr. Chaple for writing his double star column in your winter 1985 issue. I encourage him not only to continue writing it but to expand it as well!

James H. Phillips, M.D.
Roper Hospital
316 Calhoun Street
Charleston, SC 29401

Supernova Search Continues

Dear Dave/ I hope this letter finds you in excellent health and spirits. Thanks for publishing my letter concerning the amateur Supernovae Search Network. I've received quite a few responses and now have a solid foundation of observers using scopes from 8-inches to 32-inches in aperture, the latter being used for verification before reports are sent to James Bryan of Texas for confirmation. I know the project will be rewarding.

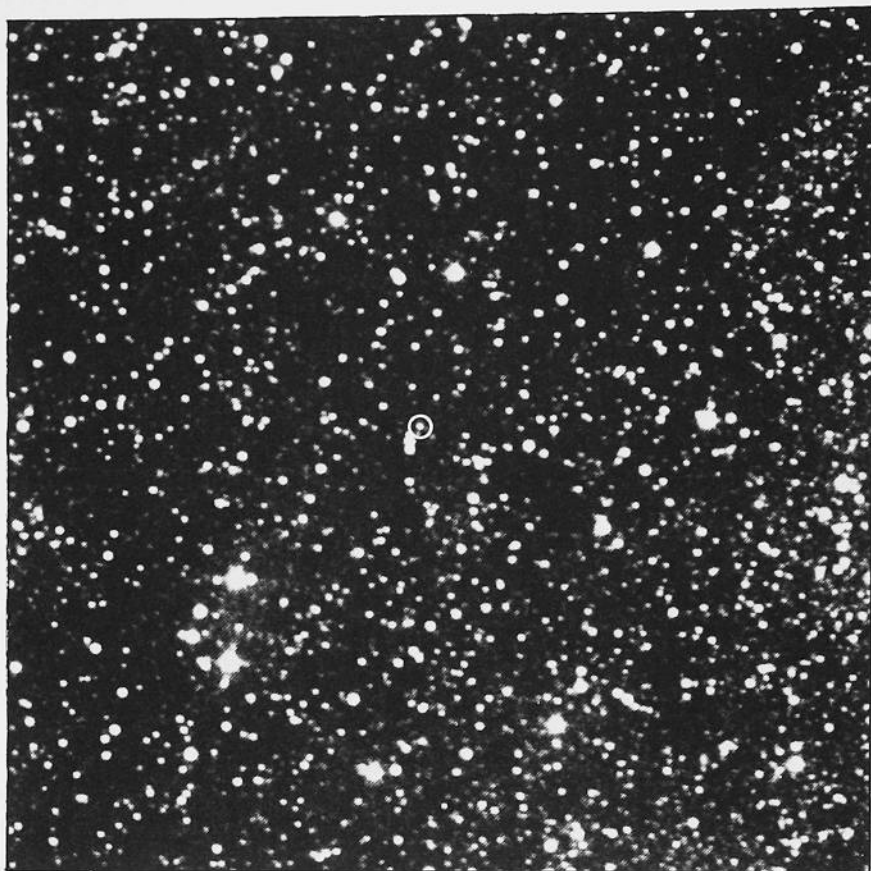
Steve H. Lucas
14400 South Kolin Avenue
Midlothian, IL 60445

Photo Oddities

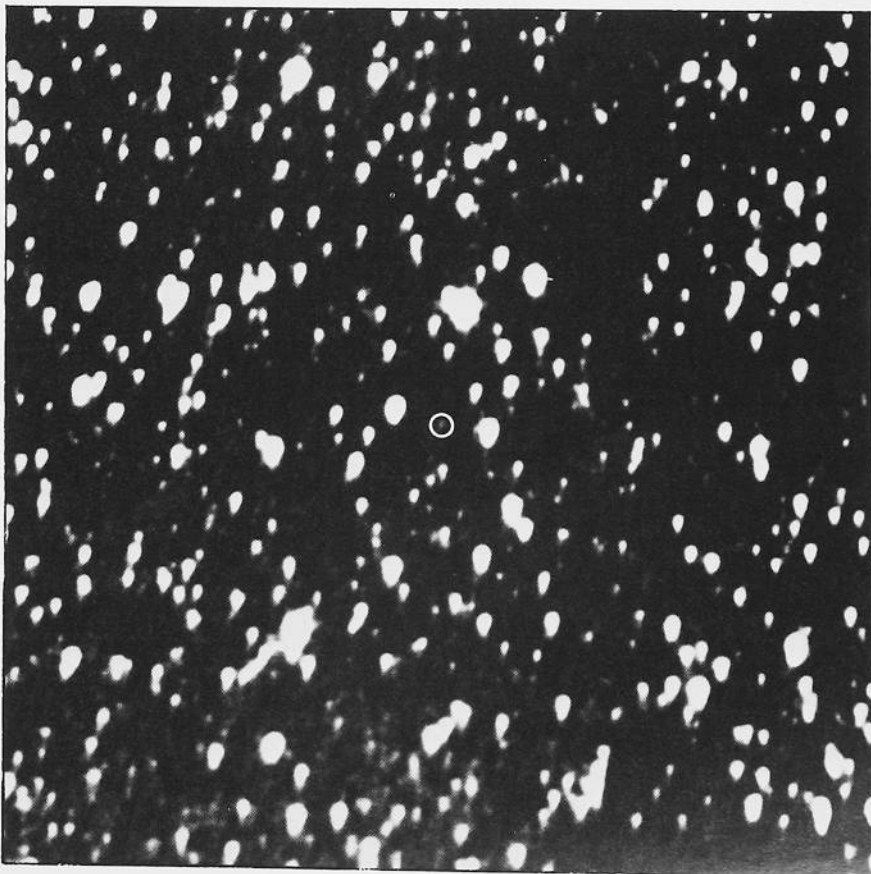
Dear Dave / Enclosed are some of the better photos from my September photographic trip to Arizona. I'm re-familiarizing myself with the Schmidt camera in hopes of taking it to Peru in April.

The photo of SS-433 is sort of an oddity — I don't think it's been photographed before by an amateur. And I think I may hold the amateur distance record with this photo of quasar S5 0014 +81. It is supposedly more than 10 billion light-years away.

Dave Healy
55 Lake Road
Manhasset, NY 11030



Above: SS-433 photographed using an 8-inch f/1.5 Schmidt camera, hypersensitized Tech Pan film, and a 9-minute exposure. Below: The quasar S5 0014+81 in Cepheus (position: Oh 17m 8s, +81° 36' 8", epoch 2000.0) photographed with an 8-inch scope hypered Tech Pan, and a 10-minute exposure. This quasar lies more than 10 billion light-years away. Photos by David Healy.



Summer's Multitude of Planetaries

by Jack B. Marling

On the next clear dark night, go outside and look up at the wispy summer Milky Way. Stretching from Cassiopeia in the north to Centaurus in the south, this band of milky light is part of our galaxy seen from within. Embedded there are hundreds of planetary nebulae — the last remnants of dying stars. Prepare for a tour of the 255 best planetaries in the summer sky.



Summer Planetaries in the Eyepiece

The little nebulae come alive in big telescopes...

The following descriptions were made by Jack Marling (JM), Steve Gottlieb (SG), Tokuo Nakamoto (TN), and Dana Patchick (DP). For obscure objects, the date of first sighting is included. Following the name of the planetary is the date and initials of the observer, followed by the aperture of the telescope used, the magnification used, and a

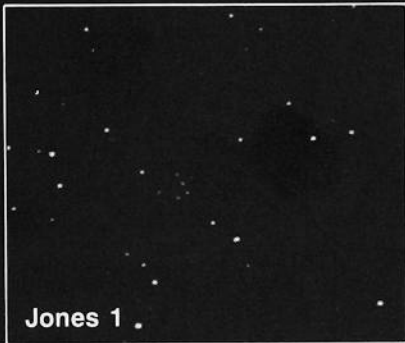
brief visual description. Observations by Deep Sky readers will be beneficial to the art of observational astronomy; send them to DSM. Who knows — you could be the first person to see some of the more obscure planetaries, especially if you observe from a southern latitude.

Henize 2-141. Not yet observed? The He 2-... planetaries were discovered photographically by Karl Henize (who is currently a NASA astronaut) and listed in a large paper published in 1964.

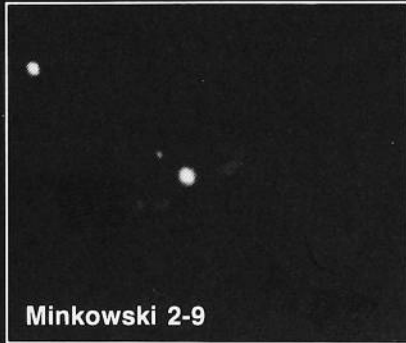
Henize 2-143. Not yet observed?

NGC 6026. TN, 14-inch scope: Faint, not too small, 12.7 magnitude star near nebula's center, a hint of annularity. JM, 18-inch scope at 220x + UHC filter: Faint, elongated ring shaped nebula with a pretty bright central star.

Longmore 11. JM, 24-inch scope at 110x + O III filter on 12 May 1985: extremely faint, a 16th or 17th magnitude object visible only with averted vision. Longmore 11 was discovered photographically in 1977.



Jones 1



Minkowski 2-9



Henize 2-207

NGC 6058. JM, 18-inch scope at 220x + UHC filter: circular, brighter in the middle, with a pretty bright nucleus. NGC 6058 has a low surface brightness.

Longmore 13. JM, 18-inch scope at 150x + O III filter on 30 March 1985: very faint, only visible part of the time with averted vision.

Henize 2-146. JM, 24-inch scope at 290x + UHC filter on 22 June 1985: pretty faint nebula, round, slightly brighter on rims (annular), north of a bright star.

IC 4593. With a 7th magnitude surface brightness, IC 4593 is bright and compact — you should see color in it.

NGC 6072. TN, 14-inch scope at 140x: Large, weakly-defined edges, brighter toward

center, slightly oval, no central star visible.

Menzel 2. JM, 24-inch scope at 290x + UHC filter on 22 June 1985: bright ring, elongated.

Henize 2-152. JM, 24-inch scope at 440x + Deep Sky filter on 18 June 1985: round uniform disk, no interior star visible.

Henize 2-153. JM, 24-inch scope at 290x + UHC filter: faint but easily visible, uniformly-lit disk.

Menzel 3. JM, June 1985: "I observed this planetary, but recorded no notes. Since it was from Mauna Kea, I'll blame it on the lack of oxygen at 14,000' elevation."

Henize 2-155. JM, 18-inch scope at 80x on 30 March 1985: small, with a bright core; best with a UHC filter. Slightly dimmer than IC

4637.

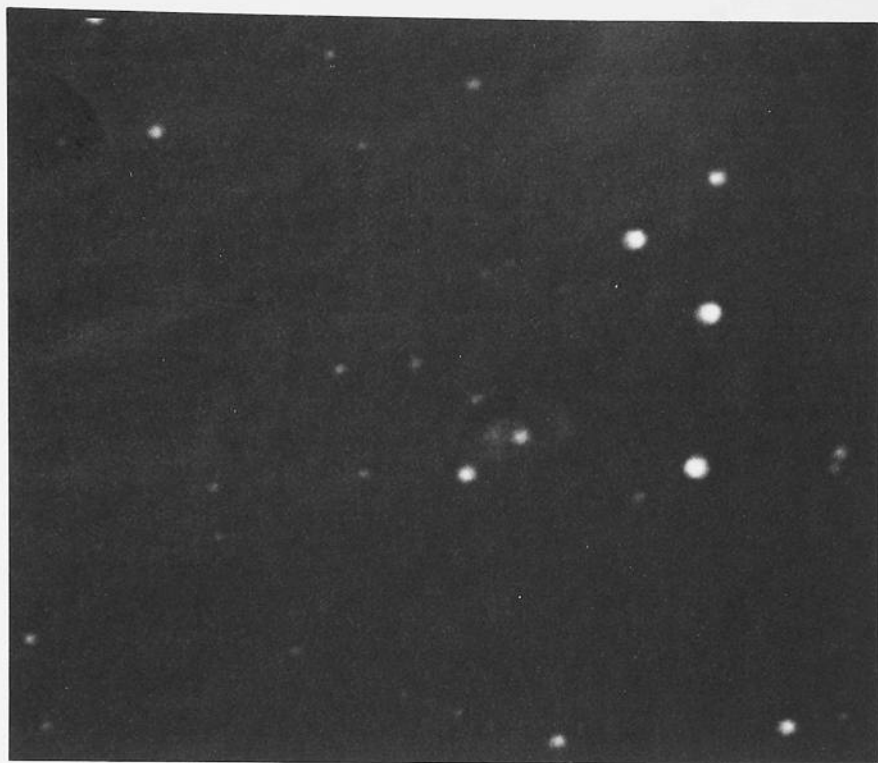
Shane 1. JM, 18-inch scope at 80x on 23 May 1985: stellar planetary found by using an O III filter.

Perek 1-6. Discovered by Perek in 1960. Not yet observed?

Henize 2-159. JM, 24-inch scope at 290x + UHC filter on 22 June 1985: Fairly bright nebula south of a star; elongated, uniform, no interior star visible.

Henize 2-163. Not yet observed?

Abell 39. TN, 30-inch f/6 scope on 30 April 1981: very large, extremely faint, round. Next to impossible to see without filter. **DP**, 16-inch f/6 scope at 97x on 30 May 1981: clearly visible at magnitude 13 or 14, uniformly diffuse, hazy edges, very round. **DP**, 8-inch



Menzel 3 in the southern constellation **Norma** is a ruddy bipolar nebula spanning 35" x 16" and glowing softly at magnitude 13.8. Its 14th magnitude central star is visible in large amateur scopes.

Probably every reader of *Deep Sky* has seen the famous Ring Nebula, M57, in the small but bright constellation Lyra. (If you haven't, it's probably because you just bought a new telescope and the sky has been cloudy.) This well-known object is undoubtedly the most frequently observed planetary nebula and is a favorite among virtually all deep-sky observers.

Only three other Messier objects are planetaries: M27, the Dumbbell Nebula

in Vulpecula; M76, the Little Dumbbell Nebula in Perseus; and M97, the Owl Nebula in Ursa Major. Most of the remaining 255 planetaries in the summer sky are either faint or very small (or both) and were catalogued haphazardly by astronomers such as Abell, Henize, or Minkowski. This doesn't mean that they are exceedingly difficult to observe, however. On the contrary, a 6-inch or 8-inch telescope under a dark sky is capable of showing the great bulk of these objects. Many of these nebulae will be "new" to even experienced observers of planetaries and it's quite likely that some have never been visually observed.

Planetary nebulae are enjoyable to observe for several reasons. They are distributed all along the Milky Way and some can be viewed during all four seasons, unlike globulars (concentrated in the spring and summer skies) or galaxies (predominantly found in the

spring and fall skies).

Planetaries come in all sizes and shapes. They range in size from stellar objects like NGC 6807 in Aquila to giant NGC 7293 in Aquarius, an object that spans half a Moon's diameter. The shapes of planetary nebulae vary from disks like NGC 6781 in Aquila to rings like M57, to bipolar objects like Minkowski 2-9 in Ophiuchus to double-shelled nebulae like NGC 6804 in Aquila and NGC 1535 in Eridanus. For background information on planetary nebulae, see "Observing Planetary Nebulae" and "What Makes a Planetary Nebula?," both in *Deep Sky* #6 (Spring 1984).

A less important reason for observing planetaries is that, by and large, they are visible under slight to moderate light pollution by virtue of their high surface brightnesses. Unlike galaxies, which require a very dark sky to reveal their low-contrast details, many planetaries are bright enough or small enough to be seen well from suburbia. Indeed, some planetaries are so bright that they show color; this occurs when their surface brightnesses exceed about 8th magnitude per square arcminute, supplying enough light to "turn on" your eye's cone receptors. And because the visible light from planetary nebulae is limited to two or three discrete emission lines, their visibility can be greatly enhanced by one of the new generation nebula filters.

Most observing reference books list about 60 planetaries located between 16 and 22 hours right ascension. In researching the professional literature, however, I discovered information on some 500 "bright" summer planetary nebulae that may be visible in backyard telescopes of 17.5-inches or less aperture. This does not include some 400 objects that were deemed too faint or too small.

The basic information about planetaries, particularly magnitudes, is in a complex state of disarray. Photographic magnitudes are typically provided, but they generally run faint compared to v magnitudes and can be

scope at 44x + filter on 3 July 1981: visible with averted vision and considerable concentration. **JM**, 18-inch scope at 80x + O III filter: faint round planetary with 13th magnitude star on its edge.

Henize 2-164. **JM**, 24-inch scope at 290x + UHC filter on 19 June 1985: pretty bright round nebula, uniformly lit, no interior star visible.

Henize 2-165. **JM**, 24-inch scope at 290x + UHC filter on 19 June 1985: large low surface brightness nebula with a uniformly lit disk.

NGC 6153. **JM**, 24-inch scope at 480x: ring shaped with a bright interior; no central star visible.

Henize 2-175. Not yet observed?

PC 12. **JM**, 18-inch scope at 80x + UHC filter: faint stellar planetary. Discovered by Minkowski in 1957.

NGC 6210. **JM**, 18-inch scope at 420x: small bright planetary, brighter in its middle, featureless, and no central star visible.

Henize 2-186. Not yet observed?

Minkowski 2-5. Not yet observed?

Haro 2-1. Not yet observed?

IC 4637. **TN**, 14-inch scope on 3 April 1981: no color visible, appears a magnitude brighter than IC 4663, central star visible. **JM**, 24-inch scope at 500x on 21 June 1985: nice planetary around 12th magnitude, central star visible, diameter = 20".

PC 14. Not yet observed?

Minkowski 2-9. M 2-9 is a fine example of

a bipolar nebula — it has a bright core and two elongated wings or lobes. **JM**, 18-inch scope at 150x + UHC filter on 23 April 1985: faint, very elongated nebula, visible best with UHC filter. **DP**, 17.5-inch scope at 100x: appears as a group of three nebulous "stars."

Henize 2-198. **JM**, 20-inch scope at 200x + UHC filter on 14 May 1985: pretty bright nebula of 13th or 14th magnitude; diameter = 20", uniformly-lit disk, no central star visible. **DP**, 17.5-inch scope at 160x + Henz 300 filter on 15 June 1985: visible nearly continuously with averted vision; shapeless, diameter = 25".

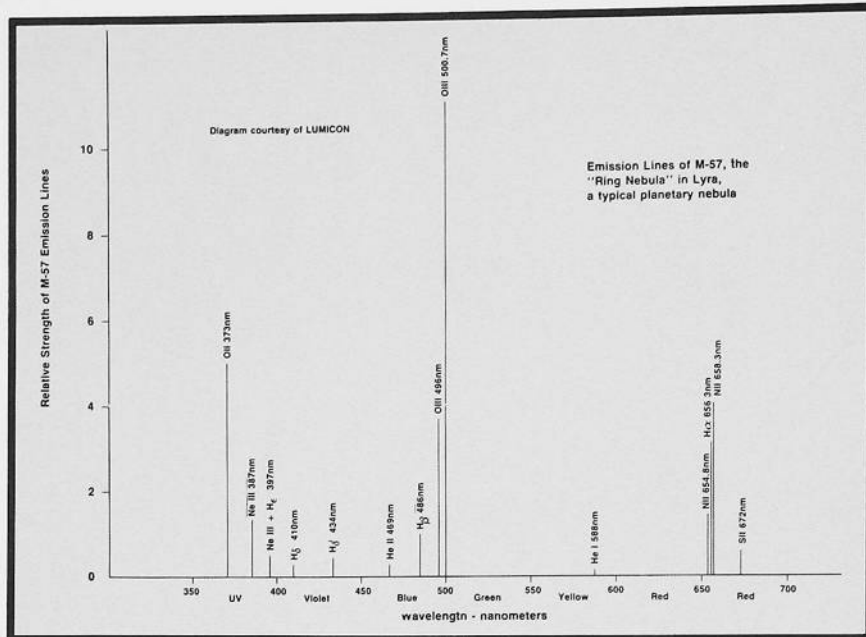
Haro 1-6. **DP**, 17.5-inch scope at 160x on 15 June 1985: Stellar without filter and no

as much as two magnitudes off from V in either direction. This potential error window of four magnitudes makes observing them highly unpredictable: a 14th-magnitude planetary at the limit of your scope could actually appear as a 12th- or 16th-magnitude nebulosity.

To help remedy this, I have calculated visual magnitudes for these planetaries based on modern photoelectric and spectrographic studies. The energy of each emission line in a planetary was convolved with the scotopic (rod) response of the dark-adapted human eye to determine the "perceivable energy" coming from any given planetary. These data were then calibrated against Vega as a standard star and visual magnitudes were derived that should be accurate to within 0.15 magnitude, on the average. Brian Skiff at Lowell Observatory assisted in the calibration process and Jim Kaler at the University of Illinois assisted in tracking down photometric data.

Observing Planetaries

Most observers believe that deep-sky objects are static in number, having all been found by Messier, the Herschels, and others in the 18th and 19th centuries. Actually, new planetaries (and other objects) are discovered every year! Most are discovered by examining



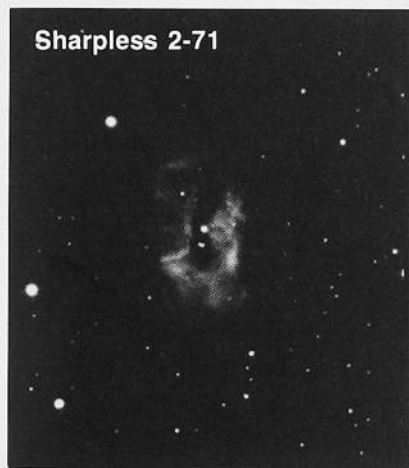
photographic plates for objects that show a characteristic round morphology, or more likely show strong emission features other than hydrogen lines or have very blue central stars. For our purposes, I've chosen mostly bright and large objects easily observable in amateur instruments; objects under 50 in diameter or fainter than 16th magnitude have been excluded from the table.

Since most planetaries are discovered photographically, it's quite possible that relatively new, faint objects have never been observed visually. The table includes many planetaries that, to the best of my knowledge, have never been observed — you could be the first to make a visual sighting of one of these objects! There are two fundamental reasons for this. First, most backyard astronomers don't know about the more obscure planetaries since they aren't listed in easily accessible catalogues. Second, professional astronomers normally don't look at objects visually and probably believe that many of these fainter objects can't be visually observ-

ed.

The late George O. Abell, who was Professor of Astronomy at the University of California at Los Angeles, was well-known for discovering 86 large, low surface brightness planetaries on Palomar Sky Survey plates in the 1960s. These nebulae were designated Abell 1 through Abell 86. In 1981, Professor Abell wrote to the California observer Tokuo Nakamoto about the prospects of seeing these faint nebulae. Wrote Abell, "I should caution you that most [of the planetaries] are extremely faint, and I think will be impossible to see visually through a telescope, although you may be able to photograph some." Remarkable as it may now seem, I believe over half of the Abell planetaries have been observed by amateurs, although a good nebula filter is usually a must.

Besides getting enjoyment from observing a planetary, backyard observers can make useful contributions to the pool of knowledge about these celestial puffsballs. Often, as we said earlier, a planetary's magnitude is



disk perceived at 300x; image repressed to invisibility with DS 300 filter.

IC 4642. Not yet observed?

Minkowski 3-36. Not yet observed?

Nassau 1. **TN** and **DP**, 14-inch scope at 130x on 14 September 1985: Appears as a 13th magnitude stellar object.

NGC 6302. The "Bug Nebula" is a real showpiece, and is either a bipolar planetary or another strange type of emission nebula. **JM**, 24-inch scope at 300x on 30 May 1981: bright with an exotic shape, a bright core may be the central star, appears quite elongated.

Sanduleak 4-1. Discovered in 1983. **TN**, 14-inch scope at 130x on 18 May 1985: Appears to be about magnitude 13.7 with a 14th magnitude central star. Appears slightly

oval in shape. **DP**, 17.5-inch scope at 160x on 25 May 1985: appears as a 15" diameter disk with a faint central star. An 8-inch scope at 100x shows the same size disk without the central star. A filter only seems to repress this object.

NGC 6309. **JM**, 18-inch scope at 420x + Deep-Sky filter: an attractive nebula elongated north-south and lying less than 1' from a field star. No central star visible.

Minkowski 2-10. Not yet observed?

Henize 2-207. **JM**, 20-inch scope at 200x + UHC filter on 14 May 1985: lovely 13th magnitude bipolar nebula. Said Marling: "Along with Pierre Schwaar, I observed this object and Henize 2-108, He 2-198, and He 2-207 using his 20-inch scope at the 1985

Texas Star Party."

NGC 6326. **TN**, 14-inch scope at 76x on 17 July 1982: fairly bright with a noticeable disk.

Minkowski 2-11. Not yet observed?

NGC 6337. A superb ring-shaped planetary in Scorpius. **JM**, 24-inch scope on 30 May 1981: subtle elongated ring with an off-centered star inside. **JM**, 18-inch scope at 150x + UHC filter on 23 April 1985: circular ring with very dark hole inside, off-centered interior star is about 15th magnitude.

Minkowski 3-7. Not yet observed?

Minkowski 3-8. Not yet observed?

Haro 1-13. Not yet observed?

Minkowski 3-10. Not yet observed?



NGC 6563 is a bright ring-shaped nebula lying in the constellation Sagittarius. It measures 50" x 37" and contains a central star impossibly faint for backyard observers (magnitude 18.3).

unknown or badly in error and sometimes sizes are also unknown, or in need of significant revision. Magnitude and size estimating can provide useful information for the study of obscure planetaries about which little is known. Some filters will allow you to make qualitative estimates of the relative strengths of various emission lines in a nebula, data which is again unknown for many planetaries.

Visual Magnitudes

For once, nature has conspired to

make things easy on astronomers: the peak sensitivity of a dark-adapted human eye matches the wavelength of the strongest emission lines in planetary nebulae.

Take M57, the Ring Nebula, for example. In it, the strong emission lines are concentrated in the near-ultraviolet (ionized oxygen [O II] and doubly-ionized neon [Ne III] lines), in the visible part of the spectrum (doubly-ionized oxygen [O III] lines), and in the red (ionized nitrogen [N II] and hydrogen-alpha [H α] lines). During the daytime, bright red and near-ultraviolet light can be perceived by the cone receptors utilized by human eyes for color vision. But at night, the cones don't "work" under dim light conditions; the job of seeing faint light is left to the eyes' rod receptors.

Knowing the precise locations of the greatest intensities in a planetary nebula's light make it possible to

calculate the nebula's total energy flux and therefore derive a true visual magnitude for the object. These data for 255 summer planetaries appear in the table on pages 00 and 00.

But simply using visual magnitudes as indicators of a nebula's visibility isn't good enough; there's another factor involved. Observationally, a more important piece of information is surface brightness: the magnitude of an object per unit of surface area. If you know the visual magnitude and size of a nebulous object, you can compute its surface brightness by using the following formula:

$$SB = m_v + \frac{1}{0.92} \ln \left(\frac{\pi ab}{\pi 60^2} \right) = m_v + \frac{1}{0.92} \ln \left(\frac{ab}{3600} \right)$$

where m_v = true visual magnitude; a = major (long) axis in arcseconds; b = minor (short) axis in arcseconds; and $\ln$ = the natural logarithm.

The formula calculates the ratio of the area of a generally elliptical nebula (given by the quantity $\pi/4ab$) to the area of a circular nebula measuring 60" across (given by the quantity $\pi/4 \cdot 60^2$). Thus a surface brightness computed by this formula gives a nebular magnitude if the object has a uniform surface brightness over a 60" diameter. For example, to calculate the surface brightness of a planetary of magnitude 14 that measures 30" across, the formula becomes:

$$SB = 14 + \frac{1}{0.92} \ln \left(\frac{30 \times 30}{3600} \right) = 14 - 1.5 = 12.5$$

This formula can also be used to calculate the surface brightnesses of galaxies or other types of nebulae.

How faint a surface brightness can you observe with backyard equipment? Using specially-designed filters, I've observed planetary nebulae down to $SB = 16.5$ magnitudes per square arcminute. If this is a reasonable threshold level, then the limiting surface brightness for seeing color in a planetary should be about 1,000 times greater, or about $SB = 8.5$. This corresponds well with what many observers report, namely that planetary nebulae

Abell 41. DP, 30-inch scope at 230x on 23 May 1982: small, not too bright, 16th magnitude central star visible.

NGC 6369. JM, 24-inch scope at 480x on 28 June 1984: a bright circular ring containing an easily-visible 15th magnitude central star.

Haro 1-24. Not yet observed?

Haro 2-15. Not yet observed?

PC 17. Discovered by Peimbert & Costero in 1961; not yet observed?

Minkowski 1-22. Not yet observed?

Minkowski 3-11. Not yet observed?

Longmore 16. This large (83" diameter) planetary was discovered by Longmore in 1977. JM, 18-inch scope at 80x + UHC filter on 23 May 1985: a pretty large, round nebula

slightly brighter in its middle. Probably 13th or 14th magnitude.

Minkowski 1-23. Not yet observed?

Minkowski 1-24. Not yet observed?

Minkowski 1-25. Not yet observed?

Kohoutek 1-4. Discovered by Kohoutek in 1962. JM, 18-inch scope at 150x + O III filter on 25 May 1985: an extremely faint object at the limit of averted vision. A 12th magnitude star touches the nebula's northern edge.

Hubble 4. Not yet observed?

Kohoutek 1-14. Discovered by Kohoutek in 1962. JM, 18-inch scope at 150x + O III filter on 25 May 1985: very faint object whose bright central star makes it hard to see the nebulosity. DP, 17.5-inch scope at 160x +

DS 300 filter on 13 July 1985: A uniformly faint halo without any hint of annularity.

Haro 1-28. Not yet observed?

IC 4663. TN, 10-inch f/7 scope on 3 April 1981: a faint stellar object.

Thackeray 1. A 12th magnitude planetary discovered by Thackeray in 1950. TN, 14-inch scope on 16 July 1985: easily observed a 12th magnitude central star but found no nebulosity.

Minkowski 1-26. Not yet observed?

Minkowski 2-15. Not yet observed?

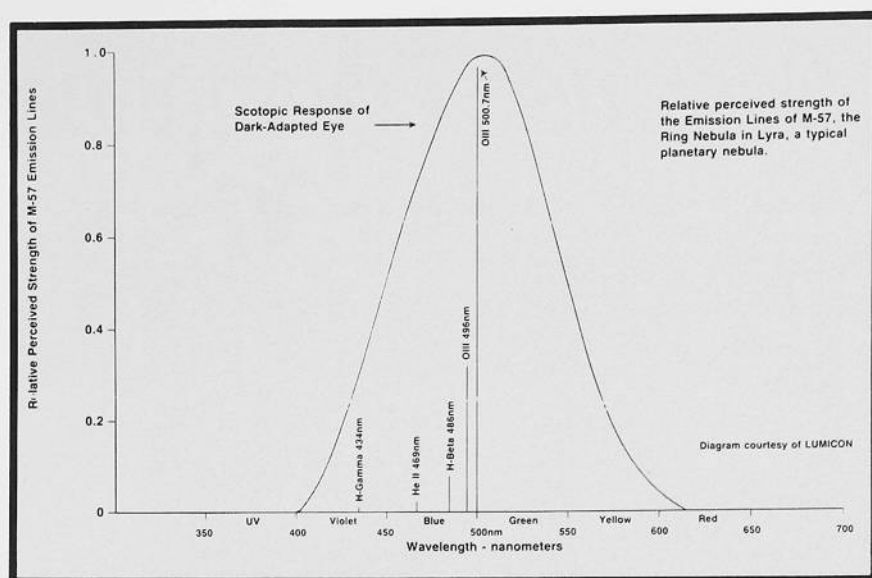
Hubble 5. A 12th magnitude planetary discovered by Hubble in 1921. JM, 24-inch scope at 280x + UHC filter on 23 June 1985: a small, faint nebula with a bright core and extensions running north and south.

with surface brightnesses greater than 8 show color visually.

The surface brightness of M57 in Lyra is about 9.2, making it slightly too faint to show color in backyard telescopes. Using a 36-inch scope I did not see color in M57, but some people did. NGC 6826, the "Blinking Planetary" in Cygnus, has a surface brightness of 6.9. With the same 36-inch scope on the same night, it displayed a lovely bluish-green cast. The well-known Dumbbell Nebula, M27, has an integrated magnitude of 7.3 and is easily visible in finderscopes and binoculars, but its large size of 480" x 340" gives it a rather dim surface brightness of 11.4. The brightest planetary in the sky, NGC 7293 in Aquarius, has a total magnitude of 6.5. Its light is spread over 900" x 720", making its surface brightness a dismal 13. Expect to see color in any planetary whose surface brightness exceeds 8 magnitudes per square arcminute.

Filters for Observing

Properly designed nebula filters can be an important tool in observing planetaries. In particular, filters that give greater than 90% transmission of the strong doubly-ionized oxygen (O III) lines at 496 and 501 nanometers will not dim the nebula substantially but will



darken the sky background.

The contrast gain that a filter provides depends solely on its bandpass. The visible bandpass of a filter is given in nanometers and is the region of high transmission centered on the three main nebular lines at 486, 496, and 501 nm. If centered on about 490 nm, a wide (60 to 90 nm) bandpass filter covers enough to pass all three of these primary lines as well as the weaker ionized helium line at 469 nm. However, such a wide bandpass permits more residual background skyglow than a narrower bandpass filter, causing the sky to appear gray rather than black. Because of this property, wide bandpass filters work best at high magnification on planetary nebulae that have high surface brightnesses. In this case, "high magnification" means a resulting exit pupil of 1 to 3 mm. (an exit pupil is simply the eyepiece focal length divided by the telescope's focal ratio). Using a popular 8-inch f/10 SCT, for example, gives an 80-inch (2000 mm) focal length; a 15 mm eyepiece giving 130x would produce an exit pupil of 1.5 mm.

Narrower bandpass filters work best for general observing of planetary

nebulae. There are two on the market that offer bandpasses of either 25 nm or 30 nm. These higher contrast filters work best at low to medium magnifications, which corresponds to 2 to 5 mm exit pupils or, in the case of an 80-inch focal length instrument, 40x to 100x. For maximum contrast on planetary nebulae, one type of filter is available that gives a bandpass of only 12 nm and transmits only the two oxygen III lines at 496 and 501 nm. This filter works best at low magnifications, giving an exit pupil of 4 to 7 mm. Such a narrow bandpass filter on a large backyard telescope will show planetary nebulae down to a surface brightness of 16 magnitudes per square arcminute. To best observe central stars, by the way, use no filter at all and employ high magnification.

Photographing Planetaries

Bright planetaries are rather easy to photograph using backyard telescopes. To make some of the photos of planetaries in this article, I used a very "fast" telescope — a 17.5-inch f/4.5 reflector — for low-surface brightness objects like the Helical Nebula, and a long focal length telescope (to give



NGC 6439. A compact 13th magnitude nebula.

NGC 6445. **SG**, 13-inch scope at 288x in June 1984: elongated northwest/southeast with a faint star at the bright northwestern edge. The northwestern edge appears slightly curved while the other sides are straight and meet at right angles.

Minkowski 1-29. A 15th or 16th magnitude fuzzball. Not yet observed?

Hartl-Tritton 6. This far southern planetary was discovered in 1985. Not yet observed?

Minkowski 2-17. Not yet observed?

Minkowski 2-16. Not yet observed?

Minkowski 1-31. Not yet observed?

Minkowski 3-16. Not yet observed?

Haro 2-29. Not yet observed?

Abell 43. **TN**, 10-inch f/5 scope on 17 April 1982: A threshold object; saw only because I checked a photo for a position. **JM**, 18-inch scope at 80x + OIII filter on 23 May 1985: a pretty easily visible, uniformly round object. **DP**, 17.5-inch f/4.5 scope at 100x + DS 300 filter on 28 May 1985: difficult without filter. Shows with filter as an 80" diameter bright ring with central star; two other stars visible inside planetary.

VY 1-2. This compact 12th magnitude planetary was discovered by Vyssotsky in 1942. **TN**, 14-inch scope at 127x on 9 July 1983: stellar without any color. **SG**, 13-inch scope at 144x in July 1985: a stellar 12th magnitude object.

Minkowski 2-20. A 15th magnitude nebula

of unknown size. Not yet observed?

Cannon 1-2. This compact planetary was discovered by Cannon in 1922. **JM**, 18-inch scope at 150x on 22 July 1985: a 12th magnitude planetary north of M7; found by blinking with an OIII filter.

Hubble 6. A compact 11th magnitude planetary. Not yet observed?

Minkowski 1-32. Not yet observed?

Haro 1-42. Discovered by Haro in 1952. Not yet observed?

Minkowski 2-21. A stellar 13th magnitude object. Not yet observed?

Minkowski 2-22. Not yet observed?

NGC 6543. **JM**, 24-inch scope at 480x on 28 June 1984: a bright planetary in Draco visible as a lovely greenish ring and bright

Summer Planetaries

Object	Con.	R.A.(2000)Dec.	Size	Mag.	Mag.*	Brightness	
						Vis.	Red.
Henize 2-141	Norma	15h59.1m -58°24'	16" x 12"	12.4	13.6	9.5	10.3
Henize 2-143	Norma	16h01.1m -55°06'	7" x 4"	15.4	—	10.7	9.3
NGC 6026	Lupus	16h01.4m -34°32'	54" x 36"	12.9	—	12.3	11.6
Longmore 11	Lupus	16h03.4m -36°01'	67" x 50"	16±1	19.0	16±1	—
NGC 6058	Hercules	16h04.4m +40°41'	24" x 21"	13.0	13.8	10.9	11.0
Longmore 13	Scorpius	16h09.8m -30°54'	71"	15-16	—	16±.5	—
Henize 2-146	Norma	16h10.7m -54°57'	24" x 20"	14.2	—	12.0	9.8
IC 4593	Hercules	16h12.2m +12°04'	13" x 10"	10.7	11.2	7.1	7.0
NGC 6072	Scorpius	16h13.0m -36°14'	70"	11.7	17.5	10.7	—
Menzel 2	Norma	16h14.5m -54°57'	25" x 21"	11.9	—	9.6	8.5
Henize 2-152	Norma	16h15.3m -49°14'	13" x 10"	13.7	—	10.1	7.5
Henize 2-153	Norma	16h17.2m -53°32'	14" x 12"	14.1	—	10.6	8.8
Menzel 3	Norma	16h17.2m -51°59'	35" x 16"	13.8	14.1	11.2	7.7
Henize 2-115	Scorpius	16h19.4m -42°16'	16" x 13"	12.3	—	9.2	9.3
Shane 1	Serpens	16h21.1m -00°17'	5"	12.8	14.7	7.4	7.1
Perek 1-6	Norma	16h23.9m -46°42'	14" x 11"	16.1	—	12.7	11.0
Henize 2-159	Norma	16h24.3m -54°36'	16" x 8"	13.9	—	10.6	9.8
Henize 2-163	Norma	16h29.6m -59°09'	22" x 18"	13.9	—	11.6	10.1
Abell 39	Hercules	16h27.5m +27°54'	170"	12.9	15.8	14.9	14.0
Henize 2-164	Norma	16h29.9m -53°23'	16"	13.7	—	10.7	9.5
Henize 2-165	Norma	16h30.0m -54°10'	54" x 45"	13.7	—	13.3	10.6
NGC 6153	Scorpius	16h31.5m -40°15'	28" x 21"	10.8	16.1	8.5	8.5
Henize 2-175	Scorpius	16h39.5m -36°35'	11" x 4"	15-16	—	11±1	9.8
Peimbert/Costerro 12	Ophiuchus	16h43.8m -18°57'	5" x 4"	13.4	14.6	7.8	7.0
NGC 6210	Hercules	16h44.5m +23°49'	20" x 13"	8.8	±.3	5.8	5.4
Henize 2-186	Ara	16h59.6m -51°42'	3"	13.3	14.5	6.8	6.4
IC 4634	Ophiuchus	17h01.6m -21°50'	11" x 9"	10.9	15.0	7.0	6.1
Minkowski 2-5	Scorpius	17h02.3m -33°10'	5.1"	13±1	—	8.9	7.0
Haro 2-1	Scorpius	17h04.6m -33°59'	5.6"	14±1	12.9	9±1	8.0
IC 4637	Scorpius	17h05.2m -40°53'	21" x 17"	12.5±1	12.3	10±1	9.0
Peimbert/Costerro 14	Ara	17h06.3m -52°27'	8" x 6"	12.6	14.8	7.9	9.0
Minkowski 2-9	Ophiuchus	17h05.7m -10°09'	39" x 15"	14.6	—	12.4	10.0
Henize 2-198	Scorpius	17h08.4m -44°13'	25" x 15"	13±1	—	10.5±1	9.8
IC 4642	Ara	17h11.8m -55°24'	18" x 15"	12.4	13.6	9.5	9.3
Minkowski 3-36	Ophiuchus	17h12.6m -25°44'	5" x 4"	15±1	—	10±1	9.0
Nassau 1	Ophiuchus	17h12.9m -33°16'	Stellar	13.4	16.7	—	—
NGC 6302	Scorpius	17h13.7m -37°06'	83" x 24"	9.6	—	9.1	7.2
Sanduleak 4-1	Hercules	17h13.8m +49°16'	15"	14.5±1	12-13	11.5±1	10.5
NGC 6309	Ophiuchus	17h14.1m -12°55'	22" x 12"	11.5	13.7	10.3	9.7
Minkowski 2-10	Scorpius	17h14.1m -31°20'	5" x 3"	15±1	—	9-10	9.0
Henize 2-207	Scorpius	17h19.5m -45°53'	40" x 26"	12-13	—	11-12	8.8
NGC 6326	Ara	17h20.8m -51°45'	16" x 11"	11.0	13.5	7.7	7.3
Minkowski 2-11	Ophiuchus	17h20.6m -29°01'	11"	13.3	—	9.5	9
NGC 6337	Scorpius	17h22.3m -38°29'	49" x 45"	12.3	14.8	11.8	12.0
Minkowski 3-7	Ophiuchus	17h24.6m -29°24'	7" x 6"	15.2	18.0	10.4	8.0
Minkowski 3-8	Ophiuchus	17h24.9m -28°06'	5.6" x 5.4"	14±1	—	9±1	7.0
Haro 1-13	Scorpius	17h28.5m -35°08'	13" x 11"	15±1	—	11±1	9.5
Minkowski 3-10	Ophiuchus	17h28.7m -28°27'	4" x 3"	13.6	—	7.6	7.0
Abell 41	Scorpius	17h29.0m -15°13'	16" x 7"	15-16	16.0	12.5	10.9
NGC 6369	Ophiuchus	17h29.3m -23°46'	30"	11.4	14.7	10.0	9.0
Haro 1-24	Ophiuchus	17h33.6m -21°46'	8.5"	15±1	—	11±1	9.0
Haro 2-15	Ophiuchus	17h34.4m -22°53'	5" x 4"	15±1	—	11±1	8.8
Peimbert/Costerro 17	Ara	17h35.8m -47°00'	6"	14.1	—	9.1	7.5
Minkowski 1-22	Ophiuchus	17h35.2m -18°34'	9"	14±1	21	10±1	10±1
Minkowski 3-11	Ophiuchus	17h35.4m -20°57'	12"	14±1	—	10±1	9.0
Longmore 16	Scorpius	17h35.7m -40°12'	83"	13-14	16.0	~14	—
Kohoutek 1-4	Ophiuchus	17h40.5m -27°01'	47" x 33"	15.5±1	19.7	15.9	12.7
Hubble 4	Ophiuchus	17h41.9m -24°42'	7" x 6"	13.0	14.9	~8.2	8.0
Kohoutek 1-14	Hercules	17h42.5m +21°27'	47"	15.1	16.4	14.6	13.8
Haro 1-28	Scorpius	17h42.9m -39°36'	8.2" x 7.6"	13.2	—	—	8.0
IC 4663	Scorpius	17h45.5m -44°54'	14" x 12"	13.0	14.0	~9.7	—
Thacker 1	Ara	17h45.6m -46°05'	13"	12.3	11.1	~8.9	6.2
Minkowski 1-26	Scorpius	17h46.0m -30°12'	5" x 4"	13.8	12.1	~8.0	4.0
Minkowski 2-15	Sagittarius	17h46.9m -16°17'	6.1" x 5.4"	14.6	—	~9.5	10.0
Hubble 5	Sagittarius	17h47.9m -30°00'	19" x 12"	11.8	—	~8.8	8.0
NGC 6439	Sagittarius	17h48.3m -16°29'	6.1" x 5.1"	12.6	18.5	~7.5	7.5
NGC 6445	Sagittarius	17h49.2m -20°01'	38" x 29"	11.2	19.2	~9.9	8.1
Minkowski 1-29	Scorpius	17h50.3m -30°35'	9" x 7"	15-16	—	12.5	8.0
Hartl/Tritton 6	Pavo	17h51.8m -60°23'	30" x 42"	15-17	~18	14-16	—
Minkowski 2-17	Sagittarius	17h52.1m -17°36'	7" x 6"	14-16	—	—	9.0
Minkowski 2-16	Scorpius	17h52.6m -32°46'	6.2" x 4.7"	14-16	—	—	9.0
Minkowski 1-31	Sagittarius	17h52.7m -22°22'	25"	13-16	—	—	—
Minkowski 3-16	Scorpius	17h52.8m -30°50'	7" x 6"	15.5	—	13.3	10.0
Haro 2-29	Scorpius	17h53.3m -32°41'	9.6" x 2.5"	14-16	21p	15	8.0
Abell 43	Ophiuchus	17h53.6m +10°37'	80" x 74"	14.6	14.7	~14.9	13.1
Vysotsky 1-2	Hercules	17h54.4m +28°00'	5.2" x 4.1"	12.0	17.6	~6.5	7.5
Minkowski 2-20	Sagittarius	17h54.5m -29°36'	25"	15.1	17.0	—	—
Cannon 2-1	Scorpius	17h54.6m -34°23'	2" x 3"	12.2	17.0	—	—
Hubble 6	Sagittarius	17h55.1m -21°45'	5"	11.0	14.7	~6.3	7.5
Minkowski 1-32	Sagittarius	17h56.3m -16°30'	8" x 7"	12-14	—	—	7.0
Haro 1-42	Scorpius	17h57.4m -33°36'	6" x 5.9"	14.3	—	~9.2	—
Minkowski 2-21	Sagittarius	17h58.1m -29°45'	3"	13.6	16.2	~6.9	—
Minkowski 2-22	Scorpius	17h58.5m -33°29'	5.6" x 5.0"	13.15	—	—	8.0
NGC 6543	Draco	17h58.6m +66°38'	22" x 19"	8.1	—	~5.7	—
Minkowski 1-33	Serpens	17h59.0m -15°32'	5" x 5"	13.0	—	—	7.0

Object	Con.	R.A.(2000)Dec.	Size	Mag.	Mag.*	Brightness	
						Vis.	Red.
Minkowski 3-20	Sagittarius	17h59.3m -28°14'	4"	14.3	—	~8.4	—
Fleming 3	Corona Aus.	18h00.2m -38°50'	25"	11.4	—	—	—
Perek 1-11	Sagittarius	18h01.7m -33°15'	10" x 8"	13-15	—	—	9.0
Minkowski 2-23	Sagittarius	18h01.7m -28°26'	2"	12.4	—	5.0	—
Minkowski 2-24	Sagittarius	18h02.0m -34°28'	11" x 4"	14.7	18.0	~10.0	9.0
IC 4673	Sagittarius	18h03.3m -27°06'	18" x 18"	13.0	14.6	~10.0	10.0
Minkowski 1-35	Sagittarius	18h03.7m -26°44'	5"	14.6	—	~9.3	8.0
Minkowski 2-27	Sagittarius	18h03.9m -31°18'	2"	14.2	—	~6.8	—
Haro 1-50	Sagittarius	18h03.9m -32°42'	10"	14.5	—	10.6	—
NGC 6537	Sagittarius	18h05.2m -19°51'	11" x 9"	11.6	19.5	~9.2	9.0
Haro 1-54	Sagittarius	18h07.1m -29°13'	2"	14.2	14.8	6.9	5.2
Minkowski 3-23	Sagittarius	18h07.1m -30°34'	10"	15-16	—	12.5	10.0
Shapley 3	Ara	18h07.4m -51°03'	36"	11.9	—	10.8	—
Minkowski 3-24	Sagittarius	18h07.9m -25°24'	10" x 10"	13-15	—	—	9.0
Minkowski 1-40	Sagittarius	18h08.4m -22°17'	11" x 8"	13.9	15.0	~9.9	9.0
Minkowski 1-42	Sagittarius	18h11.1m -28°59'	9" x 7"	13.3	—	—	9.0
Haro 1-59	Sagittarius	18h11.5m -27°46'	7" x 5"	14.3	—	~9.3	9.0
Minkowski 1-43	Sagittarius	18h11.8m -18°46'	6.5" x 4.3"	15-16	—	—	9.0
NGC 6565	Sagittarius	18h11.9m -28°11'	10" x 8"	11.5	19.5	~7.3	8.0
NGC 6563	Sagittarius	18h12.0m -33°52'	50" x 37"	10.9	18.3	10.2	10.0
NGC 6572	Ophiuchus	18h12.1m +06°51'	16" x 13"	7.9	11.2	~4.8	6.0
Minkowski 2-30	Sagittarius	18h12.6m -27°58'	4"	13.1	—	~7.2	—
NGC 6567	Sagittarius	18h13.7m -19°05'	11" x 7"	10.9	~15.0	~6.8	—
Minkowski 4-9	Sagittarius	18h14.3m -04°59'	46" x 38"	~14.0	19.7	14.4	11.5
Minkowski 2-33	Sagittarius	18h15.1m -30°16'	5" x 4"	14-16	—	—	8.5
Cannon MY 17	Sagittarius	18h15.4m -30°32'	10"	14.0	12.5	—	—
Minkowski 3-25	Serpens	18h15.3m -10°10'	4"	~12.5	—	~6.5	—
Minkowski 3-26	Sagittarius	18h16.2m -27°15'	8" x 7"	14-16	—	—	9.5
NGC 6578	Sagittarius	18h16.3m -20°27'	13" x 10"	13.3	14.0	~9.6	7.7
Minkowski 1-44	Sagittarius	18h16.3m -27°05'	4"	~13.7	12.5	—	8.0
Minkowski 2-34	Sagittarius	18h17.3m -23°59'	13" x 6"	14-16	—	—	9.5
Cannon 3-1	Ophiuchus	18h17.6m +10°09'	7" x 6"	13.5	13.0	~8.6	7.5
Minkowski 2-36	Sagittarius	18h17.7m -29°08'	9" x 5"	14-16	—	—	9.0
Haro 1-64	Sagittarius	18h18.4m -23°25'	8" x 7"	14-16	—	—	9.5
IC 4699	Telescopium	18h18.5m -45°59'	~10"	13.3	—	~9.4	—
Minkowski 2-37	Sagittarius	18h18.6m -28°8'	7" x 7"	14-16	—	—	9.5
Minkowski 2-40	Serpens	18h21.4m -06°02'	6" x 5"	14-16	—	—	8.0
Kohoutek 1-16	Draco	18h21.9m +64°22'	130" x 100"	14.2	15.9	~15.6	14.1
Minkowski 2-41	Sagittarius	18h22.6m -30°44'	13"	15.8	—	12.5	11.0
Minkowski 2-42	Sagittarius	18h22.6m -24°10'	5" x 3"	13.3	—	—	8.0
NGC 6620	Sagittarius	18h23.0m -26°49'	5"	15.0	—	8.4	7.0
Haro 1-67	Sagittarius	18h25.1m -22°35'	6" x 5"	15-16	—	—	9.0
Kohoutek 2-3	Serpens	18h25.0m -01°31'	2.6"	14.5	—	—	—
NGC 6629	Sagittarius	18h25.7m -23°12'	16" x 14"	11.2	12.6	~8.2	—
Longmore 17	Corona Aus.	18h27.8m -37°16'	104"	15-16	~16.0	~16.0	—
Vysotsky 2-1	Sagittarius	18h28.0m -26°07'	7"	13.1	—	~8.4	—
Minkowski 3-27	Hercules	18h27.8m +14°29'	—	13.9	—	—	—
Minkowski 1-46	Scutum	18h28.0m -15°33'	12" x 10"	15.6	—	—	8.0
Minkowski 1-47	Sagittarius	18h29.2m -21°47'	5"	14-16	—	—	8.0
Minkowski 1-48	Sagittarius	18h29.5m -19°06'	5"	13-15	—	—	7.0
Abell 44	Scutum	18h30.2m -16°45'	63" x 39"	15.4	—	14.7	12.4
Abell 45	Scutum	18h30.3m -11°37'	300" x 280"	12.9	20.1	16.5	14.1
Abell 46	Lyra	18h31.3m +26°56'	63" x 60"	14.3	15.7	14.4	13.6
NGC 6644	Sagittarius	18h32.6m -25°08'	2.5"	10.5	—	3.6	—
Minkowski 1-50	Sagittarius	18h33.4m -18°17'	6" x 5"	15-16	—	—	9.0
IC 4732	Sagittarius	18h34.1m -22°37'	3"	12.0	16.7	5.5	—
Allen 1	Sagittarius	18h34.9m -27°07'	14" x 13"	~16.0	18.0	~13.0	—
Minkowski 1-53	Sagittarius	18h35.8m -17°36'	7" x 6"	13.14	—	—	8.0
Minkowski 1-54	Sagittarius	18h36.2m -17°00'	17" x 10"	13-15	—	—	9.0
Minkowski 2-44	Serpens	18h37.6m -03°06'	8" x 7"	13.5	—	9.0	9.0
Minkowski 3-29	Sagittarius	18h39.5m -30°41'	8"	13-15	—	—	8.0
Minkowski 1-57	Scutum	18h40.4m -10°40'	9" x 8"	14-16	—	—	9.0
Minkowski 3-30	Scutum	18h41.3m -15°34'	16"	16.4	17.9	13.6	11.0
Minkowski 1-58	Scutum	18h43.0m -11°07'	7" x 6"	12.4	—	~7.5	9.0
Minkowski 1-59	Scutum	18h43.4m -09°05'	5" x 4"	12.4	—	6.8	6.5
Minkowski 1-60	Scutum	18h43.7m -13°45'	—	12.3	—	—	—
Henize 2-418	Sagittarius	18h44.3m -30°19'	13"	14-16	—	—	—
Minkowski 3-32	Sagittarius	18h44.7m -25°20'	7" x 5"	14-16	—	—	10.3
Peimbert/Costerro 21	Sagittarius	18h45.6m -20°35'	15" x 12"	15.7	—	12.5	13.9
IC 4776	Sagittarius	18h45.8m -33°21'	8"	10.3	14.6	5.9	—
Perek 1-16	Scutum	18h47.6m -06°54'	8" x 7"	14-16	—	—	9.5
Minkowski 3-33	Sagittarius	18h48.2m -25°29'	6" x 4"	14-16	—	—	8.5
Minkowski 1-62	Sagittarius	18h50.5m -22°35'	4"	13-15	—	—	7.0
Minkowski 1-64	Lyra	18h50.0m +35°15'	18"	13.3	—	11.2	9.0
Minkowski 1-63	Sagittarius	18h51.5m -13°11'	4"	13.2	—	—	8.0
Abell 49	Scutum	18h53.5m -06°29'	35" x 33"	16.1	21.0	15.4	12.8
NGC 6720 (M57)	Lyra	18h53.6m +33°01'	86" x 63"	8.7	15.4	9.1	9.0
IC 1295	Scutum	18h54.6m -08°50'	102" x 87"	12.7	15.0	13.8	12.8
Hubble 7	Sagittarius	18h55.6m -32°16'	4"	10.9	18.0	8.2	—
NGC 6742	Draco	18h59.3m +48°28'	31" x 30"	13.4	19.4	11.9	11.2
Abell 51	Sagittarius	19h01.1m -18°12'	64" x 58"	13.5	15.4	14.8	13.3
Sharpless 2-71	Aquila	19h02.0m +02°09'	124" x 75"	13.2	13.8	14.2	11.4
NGC 6741	Aquila	19h02.6m -00°27'	9" x 7"	11.4	14.7	7.0	5.9
Kohoutek 1-17	Sagitta	19h03.6m +19°21'	45"	~16.0	18.6	15.4	14.0
Abell 52	Aquila	19h04.5m +17°58'	37" x 34"	16.5	17.8	15.0	13.4
Hubble 8	Sagittarius	19h05.6m -33°12'	~2"	12.9	15.7	~5.5	—
NGC 6751	Aquila	19h05.9m -05°60'	21"	11.9	12.9	~9.7	~8.3
Abell 53	Aquila	19h06.8m +06°24'	30" x 27"	15.5	20.5	~13.8	11.4
Abell 55	Aquila	19h10.5m -02°21'	47" x 32"	15.0	19.9	14.8	12.2

Object	Con.	R.A.(2000)Dec.	Size	Mag.	Mag.*	Brightness	
						Vis.	Red.
NGC 6765	Lyra	19h11.1m +30°33'	38"	12.9	16.0	~11.9	~11.1
Henize 2-429	Aquila	19h13.6m +14°59'	4"	14.3	—	~8.6	7.0
Kohoutek 3-27	Lyra	19h14.5m +28°41'	16"	14.3	17.2	~11.4	10.8
NGC 6772	Aquila	19h14.6m -02°42'	70" x 56"	12.6	18.4	~12.8	10.7
IC 4846	Aquila	19h15.7m -08°59'	1.9" x 2.6"	11.9	13.7	~4.7	—
Abell 57	Vulpecula	19h17.1m +25°37'	40" x 34"	16.6	17.6	14.9	13.3
Dingle/Hartl/Weinberger 3	Sagittarius	19h17.1m -18°02'	34" x 29"	15.6	—	14.1	11.4
IC 1297	Corona	19h17.4m -39°36'	11" x 9"	—	12.9	—	7.5
NGC 6778	Aquila	19h18.5m -01°36'	25" x 19"	12.3	15.0	~10.0	~8.0
NGC 6781	Aquila	19h18.5m +06°32'	111" x 109"	11.4	15.0	~12.8	11.0
Nassau 2	Aquila	19h18.7m -11°06'	—	13.3	14.0	—	—
Abell 61	Cygnus	19h19.2m +46°15'	200"	13.0	17.4	15.4	14.0
Abell 60	Sagittarius	19h19.3m -12°16'	88" x 77"	15.4	18.0	15.7	14.0
NGC 6790	Aquila	19h22.9m +01°31'	10" x 5"	10.5	13.5	~5.9	5.3
Vysotsky 2-2	Aquila	19h24.4m +09°54'	—	12.7	13.7	—	—
Minkowski 3-34	Aquila	19h27.1m -06°35'	6" x 5"	~12.4	14.6	7.2	8.0
NGC 6803	Aquila	19h31.3m +10°03'	6"	11.4	15.2	~6.2	~5.1
NGC 6804	Aquila	19h31.6m +09°13'	42"	11.4	14.4	~10.6	~10.1
Kohoutek 1-5	Sagittarius	19h32.4m -29°24'	13" x 9"	~16.1	—	13.6	11.4
Abell 62	Aquila	19h33.3m +10°37'	161" x 151"	13.0	18.2	15.1	13.0
Henize 2-434	Pavo	19h33.8m -74°33'	8" x 6"	—	—	—	7.5
NGC 6807	Aquila	19h34.6m +05°41'	2"	12.0	13.9	~4.6	~4.4
BD +30° 3639	Cygnus	19h34.8m +30°31'	13" x 10"	11.4	10.0	—	~3.4
Minkowski 1-71	Sagittarius	19h36.5m +19°42'	5" x 3"	~13.9	—	~7.9	—
Merrill 1-1	Aquila	19h39.1m +15°56'	3"	11.8	—	~5.3	—
Minkowski 1-73	Aquila	19h41.2m +14°57'	5"	13.7	—	~8.4	~6.4
Abell 63	Sagittarius	19h42.2m +17°05'	40"	15.9	14.7	15.0	13.2
Minkowski 1-74	Aquila	19h42.3m +15°09'	9"	12.9	—	~8.8	~7.7
NGC 6818	Sagittarius	19h44.0m -14°09'	22" x 15"	9.3	13.1	~6.7	~6.6
NGC 6826	Cygnus	19h44.8m +50°32'	27" x 24"	8.8	10.6	~6.9	~6.4
Abell 64	Aquila	19h45.6m -05°35'	40" x 34"	15.3	18.1	13.7	12.2
Abell 65	Sagittarius	19h46.6m -23°08'	135" x 72"	13.1	15.9	~14.2	—
NGC 6833	Cygnus	19h49.8m +48°58'	2"	12.1	15.1	~4.7	~4.0
NGC 6842	Vulpecula	19h55.1m +29°17'	57"	13.1	16.0	~13.0	~11.9
Abell 66	Sagittarius	19h57.6m -21°37'	280" x 245"	14.1	17.4	16.5	16.7
Abell 67	Aquila	19h58.4m +03°03'	69" x 61"	15.3	18.7	15.2	14.0
Henize 1-4	Cygnus	19h59.3m +31°55'	24" x 21"	10.5	—	13.3	11.0
NGC 6853 (M27)	Vulpecula	19h59.6m +22°43'	480" x 340"	7.3	13.9	~11.4	~9.8
Abell 68	Vulpecula	20h00.2m +21°43'	42" x 34"	16.3	13.3	15.0	13.0
NGC 6852	Aquila	20h00.6m +01°44'	28"	—	—	~10.8	—
Kohoutek 3-73	Cygnus	20h03.9m +49°19'	17" x 15"	~15.7	—	12.8	11.0
Minkowski 4-17	Cygnus	20h09.0m +43°44'	23" x 21"	~12.3	—	~10.1	9.0
NGC 6884	Cygnus	20h10.4m +46°28'	6" x 5"	10.8	15.7	~5.6	~5.0
NGC 6879	Sagittarius	20h10.5m +16°55'	5"	12.5	15.0	~7.0	~6.5
NGC 6881	Cygnus	20h10.8m +37°25'	3"	13.9	16.7	~8.0	~6.0
Merrill 1-5	Sagittarius	20h11.9m +20°19'	29"	16.0	8.9	12.5	11.4
NGC 6886	Sagittarius	20h12.7m +19°59'	9"	11.4	15.7	~7.2	—
NGC 6891	Delphinus	20h15.2m +12°42'	15"	10.5	12.4	~7.5	6.7
NGC 6894	Cygnus	20h16.4m +30°34'	44"	12.3	17.6	~11.6	~9.5
IC 4997	Sagittarius	20h20.2m +16°45'	2"	10.5	14.3	~2.7	~1.6
Minkowski 3-35	Cygnus	20h21.1m +32°29'	1.5"	14.5	15.1	~6.5	~4.4
NGC 6905	Ophiuchus	20h22.4m +20°06'	44" x 37"	11.1	14.0	~10.2	~9.6
Abell 70	Aquila	20h31.6m -07°05'	45" x 40"	14.5	18.5	~13.7	~12.6
Abell 71	Cygnus	20h32.4m +47°21'	165" x 150"	13.9	18.9	~16.1	~12.7
Abell 72	Delphinus	20h50.1m +13°34'	161" x 117"	13.8	16.2	~15.6	13.9
Abell 73	Cepheus	20h56.5m +57°26'	80" x 66"	16.5	20.5	16.4	13.7
NGC 7008	Cygnus	21h00.6m +54°33'	98" x 75"	10.7	13.2	~11.5	~10.7
NGC 7009	Aquarius	21h04.2m -11°22'	30" x 26"	8.0	12.3	~6.4	~6.1
NGC 7026	Cygnus	21h06.3m +47°51'	29" x 13"	10.9	14.5	~2.4	~6.7
NGC 7027	Cygnus	21h07.0m +42°14'	18" x 11"	8.5	11.3	~5.3	~4.1
Sharpless 1-89	Cygnus	21h14.0m +47°45'	44" x 29"	14.8	19.1	13.7	11.4
NGC 7048	Cygnus	21h14.9m +46°18'	62" x 60"	12.1	18.3	~12.0	~10.2
Minkowski 1-77	Cygnus	21h19.1m +46°19'	7"	18.0	12.2	~13.3	~9.1
Minkowski 1-78	Cygnus	21h70.8m +51°54'	6"	15.5	—	—	12.3
Kohoutek 3-81	Cygnus	21h22.3m +38°07'	11"	15.7	—	12.0	~11.0
Abell 75	Cepheus	21h26.4m +62°53'	67" x 47"	13.2	11.3	~13.1	~12.5
Kohoutek 3-60	Cepheus	21h27.5m +57°39'	10"	15-17	—	—	—
Pease 1	Pegasus	21h30.0m +12°11'	1"	15.5	—	—	—
Kohoutek 3-62	Cygnus	21h32.0m +52°34'	2.5"	15.8	—	~8.8	6.2
Kohoutek 3-82	Cygnus	21h31.1m +50°00'	19"	14.9	19.5	12.4	~11.0
Abell 77	Cepheus	21h32.2m +55°53'	67" x 50"	15.2	15.9	~15.2	~12.2
IC 5117	Cygnus	21h32.5m +44°36'	1.6"	11.5	16.7	~3.7	~2.9
Hubble 1-2	Cygnus	21h33.2m +39°38'	5"	11.9	15.1	~6.6	~5.1
Abell 78	Cygnus	21h35.5m +31°42'	113" x 88"	13.4	13.3	~14.5	~14.4
NGC 7094	Pegasus	21h36.7m +12°47'	99" x 91"	13.4	13.6	~14.4	~13.7
Minkowski 1-79	Cygnus	21h37.0m +48°56'	39" x 27"	13.2	14.4	~11.8	~9.8
Kohoutek 3-84	Cygnus	21h38.8m +46°00'	10" x 8"	15.2	—	12.0	11.0
Kohoutek 3-63	Cepheus	21h39.2m +55°46'	8" x 6"	15.9	—	~11.3	~10.1
NGC 7139	Cepheus	21h45.9m +63°39'	86" x 70"	13.3	18.1	~13.8	~11.0
Minkowski 2-50	Cygnus	21h57.7m +51°42'	5" x 3"	14.7	—	~8.7	~8.0
IC 5148-50	Crux	21h59.6m -39°23'	120"	11±5	16.5	~12.5	12.3

Column 1: object designation. Column 2: constellation in which object lies. Column 3: coordinates for epoch 2000.0. Column 4: size in arcseconds. Column 5: photographic magnitude. Column 6: V magnitude of central star. Column 7: surface brightness in visible light. Column 8: surface brightness in red light. Compiled by J. Marling.

adequate image scale) for small planetaries. This second method is the most common since many planetaries are smaller than 30" in diameter. I was fortunate enough to use the 24-inch f/15.2 reflector operated by the U.S. Air Force on Mauna Kea, Hawaii. I occasionally used this instrument at f/9 for intermediate brightness planetaries.

The popular 8-inch f/10 SCTs or 12.5-inch f/6 reflectors will give both enough light gathering power and image scale to photograph most planetary nebulae. As far as films to use with these instruments, there are several to consider. For quite some time I used hypersensitized Fujichrome 400, emulsion 414, developed as a color negative. Unfortunately, this superb film — noted for its great red response — was discontinued in June 1984 and is no longer available in stores. The new Fujichrome 400 is three times slower in responding to the ruddy H α line so prominent in planetary nebulae.

Fortunately, there are two new excellent color films that are very well suited to photographing planetaries. The first is Konica SR 1600, a print film made by Sakura in Japan. The second is 3M 1000, a print film made in the U.S.A. As black and white films go, I

Recommended SR1600 or 3M1000 Photographic Exposures for Planetary Nebulae

Planetary Surface Brightness	Exposure (f/10) ^a	Exposure (f/5) ^a
14 (13 red)	—	2 hours
13 (12 red)	—	50 min.
12 (11 red)	sky fog limit	20 min.
11 (10 red)	filter needed (b)	8 min.
10 (9 red)	12 min.	3 min.
9 (8 red)	5 min.	1½ min.
8 (7 red)	2 min.	—
7 (6 red)	1 min.	—

a) Exposure Time using gas-hypersensitized film. Triple the time using unhypered film.
b) Sky Fog limit: Use a Deep-Sky Filter for exposures longer than 8 min. (30 min. at f/10).

recommend gas-hypered Kodak Tech Pan 2415.

The two essential bits of information needed to photograph a planetary are the telescope's f/ratio and the nebula's surface brightness; the latter is provided in the table on pages 00 and 00. For planetaries with surface brightnesses dimmer than about 11, a good photographic nebula filter will help considerably. This is because the exposure required for such a faint nebula will exceed the sky fog limit at a dark site. From suburban locations, a filter may be required for planetaries dimmer than about surface brightness 10.

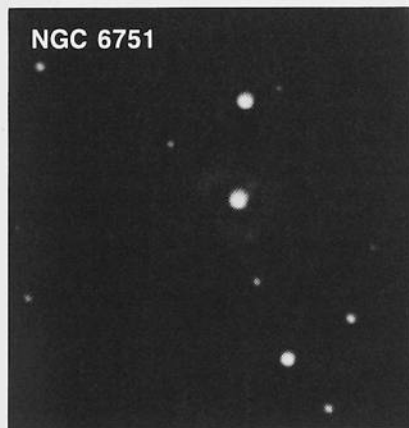
For example, suppose you want to make a nice photographic print of the Ring Nebula. You plan on using hypered Konica SR 1600 and your f/10 SCT. From the table, you see that M57 has a surface brightness of 8.8 and a red surface brightness of 7.4. From the exposure table for SR 1600, it appears you would need slightly less than five minutes' worth of exposure under a dark sky. Here's another example: suppose that you wish to photograph the lovely planetary NGC 6781 in Aquila. From the tables, you find that the visible surface brightness is 11.4 and a 45-minute exposure seems proper, but then you

note the red surface brightness of 9.3. This indicates an exposure time of only 16 minutes. The solution: if the visible and red surface brightnesses differ greatly, use the one that gives the shortest exposure. In the case of NGC 6781 you might expect the nebula to appear quite red in the photo, which is indeed the case.

Planetary nebulae offer so much variety in size, color, shape, and brightness that they are a joy to observe or photograph. This summer provides the opportunity to see a wide selection of nebulae from the comfort of your observing site, so enjoy viewing these puffballs of misty light.

A nuclear physicist, Jack B. Marling is also President of Lumicon, Inc., a California-based astronomical equipment manufacturer. He is an expert observer and photographer of the sky, and the inventor of such highly acclaimed observing tools as the UHC and Deep-Sky filters. Marling is a frequent contributor to Deep Sky and is currently working on a book about planetary nebulae. The author wishes to thank Steve Gottlieb, Tokuo Nokamoto, and Dana Patchick for providing their high-quality observations of planetaries for this article.

NGC 6751



central star. **SG**, 13-inch scope at 400x in July 1984: a very bright blue oval extended north-south with a central star just visible within the high surface brightness haze.

Minkowski 1-33. Not yet observed?

Minkowski 3-20. Not yet observed?

Fleming 3. Discovered by Fleming in 1911 and listed at photographic magnitude 11. **TN**, 30-inch scope at 160x on 8 July 1980: very small with a bluish halo and bright central star. Much easier to spot with filter.

Perek 1-11. Discovered by Perek in 1948. Not yet observed?

Minkowski 2-23. Not yet observed?

Minkowski 2-24. Not yet observed?

IC 4673, JM, 24-inch scope at 500x on 21 June 1985: elongated, slightly brighter middle, no central star.

Minkowski 1-35. Not yet observed?

Minkowski 2-27. Not yet observed?

Haro 1-50. Not yet observed?

NGC 6537, JM, 24-inch scope at 500x + Deep-Sky Filter: a compact planetary with a bright middle and no central star; seems dimmer than 13th magnitude overall. **SG**, 13-inch scope at 144x in August 1985: a 13th magnitude "star" forming the southern end of an arc of three stars. At 200x it was nonstellar, but was clearly nebular at 360x.

Haro 1-54. Not yet observed?

Minkowski 3-23. Not yet observed?

Shapley 3. Discovered by Shapley in 1936. **JM**, 24-inch scope at 240x + UHC filter on 18 June 1985: a nice roundish 12th magnitude planetary with a pretty bright central star; uniformly illuminated.

Minkowski 3-24. Not yet observed?

Minkowski 1-40. Not yet observed?

Minkowski 1-41, JM, 24-inch scope at 280x + UHC filter on 21 June 1985: a 16th magnitude planetary some 40" across; very faint, round, and slightly brighter in middle.

Minkowski 1-42. Not yet observed?

Haro 1-59. Not yet observed?

Minkowski 1-43. Not yet observed?

NGC 6565, JM, 18-inch scope at 200x on 28 July 1984: a greenish disk near four stars. **SG**, 13-inch scope at 144x + UHC filter in August 1985: a small, round, moderately bright nebula. At 360x a slight elongation is visible northwest-southeast.

NGC 6563. Photographically NGC 6563 is a bright 11th magnitude showpiece planetary with ruddy perimeter and bluish core. **SG**, 13-inch scope at 166x + UHC filter in August 1985: moderately large, slightly extended north-south, no annularity.

Small Scope Showcase

Scouting Out the Sights of Summer

by David H. Levy

*The time has come, the sunset said, to
talk of many things,
Of planets and stars and galaxies, and
planetary rings,
Of single and double and variable stars,
of distance, motion, and time;
A dream that lasts the whole night long,
when all the sky is mine.*

Summer evenings have a special feeling, for earthly nature is as active then as its celestial counterparts of the season. Let's follow our jingle literally tonight, beginning with the planet **Mars**, closer to us now than it has been in many years.

This is the year of perihelic opposition for the Red Planet, so even a small telescope will enable us to peek in on that other world. Use the highest power you can get away with — an eyepiece that allows you to see features without magnifying Mars' disk so much that it looks like quivering jelly.

Look for a polar cap, for dark markings, and especially for bright spots that could be large clouds of dust. When viewing Mars, keep in mind that you have to look through the atmospheres of two planets. So although it may be a clear, steady night here, Mars might be enveloped in a planet-wide dust storm that blocks our view of any feature.

After observing Mars, why not look at the **Moon** — an object that most die-hard deep-sky observers wish would go away. But think about it for a moment. The Moon is the only extraterrestrial object that you can actually visit with your telescope! You can explore its valleys, climb its mountains, revisit the Apollo sites. You can watch the nightly play of sunlight on the craters and even spend a whole fortnight watching the slow passage of one lunar day across a single crater.

With eyepiece and telescope, you'll soon wish to leave the solar neighborhood and look for more distant vistas. In the summer sky lie stars of all types and colors waiting for your watchful eye. If you have never looked at a star before, try **Vega** in Lyra. Not only is its bright bluish-white color apparent even in binoculars, its distance in light-years is small enough to be comprehensible: its light takes 26 years (about a generation) to reach us. Vega is also a good guidepost to the pretty double star **Epsilon (ϵ) Lyrae**, whose



The rich Milky Way starfields in southeastern Scorpius nearly mask the bright open clusters M7 (lower right) and M6 (upper right) in this long-exposure photo of the region. Photo by Martin C. Germano, using a piggybacked 135mm f/4 lens, hypered Tech Pan film, and a 20-minute exposure.

two main components are easily split using binoculars. In fact, a sharp eye can tell them apart without any optical aid on a steady night (see "Double Doubles," page 33).

Epsilon Lyrae is a double star with a twist: each component is itself a double, and with a well-adjusted, long-f/ratio 6-inch telescope you should be able to see each star split into two.

While ϵ Lyrae is not the most aesthetically pleasing of doubles, it is interesting. For real excitement, however, try β Cygni, the second brightest star in the constellation Cygnus the Swan. This star is easy to find and will treat you to a colorful display of yellow and blue. It's fun to look at and its colors are so obvious (even from city skies) that anyone can enjoy them. This star is located some

380 light-years from us, which, according to Canadian amateur astronomer Peter Jedicke, is really something to sing about — especially if you know the tune to "It's a Long Way to Tipperary":

*It's a long way to Beta Cygni, it's a long
way to go;
It's a long way to reach the double that
we call Albireo;
Good-bye, it will be centuries, 'til we're
back in town,
It's a long way to Beta Cygni, 'cause our
warp drive broke down.*

Stars can be double and they also can be variable. Although variable stars lack the star-party razzle-dazzle of doubles, they have a special beauty of their own that you can appreciate only



One of the best galaxies visible during summer is the low surface brightness face-on spiral M101 in Ursa Major. Its bright core is visible in small scopes, but the elusive arms require a dark sky coupled with at least an 8-inch scope. Photo by Brad Wallis and Robert Provin.

after watching them flow through their cycles.

Just down the neck of Cygnus from β Cyg is **Chi** (χ) **Cygni**, a variable with a period of more than a year. At minimum brightness, χ Cygni is lost in a sea of faint Milky Way stars. You'd need the patience of Job to find it without some experience. At maximum light, however, χ Cyg's story is different. While the Northern Cross is usually a four-star array, χ Cyg adds an extra light during its five weeks or so of naked-eye visibility. With a small telescope, you can follow the star as it fades through its cycle. And always record your observations, for they provide a permanent story of a page from the life of a star.

Stars, like people, enjoy group events and some of the most delightful objects

of summer are the star clusters in our galaxy. Cygnus offers a fine open cluster in **M39** and Scorpius holds **M6** and **M7**. The latter two are naked-eye visible away from cities and can be found easily; both are delights in small wide-field telescopes.

Our opening jingle now sends us out beyond our own galaxy into the realm of the heavens. We have to avoid the star-thronged Milky Way that highlights the summer sky if we wish to search for galaxies. The best summer galaxies lie to the north around the Big Dipper. The Whirlpool Galaxy, **M51**, is an absolute delight through even a small telescope — but you can't see much if you're near a city. This galaxy is located about 25 million light-years away and presents itself almost face-on, showing a magnificent pattern of spiral arms. From

one of these hangs a little companion galaxy, **NGC 5195**.

At a distance of 17 million light-years, galaxy **M101** lies closer, but it appears less distinct. Located just above the Dipper's handle, M101 is a test for small telescopes away from city lights. Whereas the features of the Whirlpool jump out of your eyepiece, those of M101 call for more patience on your part.

Oh, yes. Now for the "planetary ring," the **Ring Nebula** (**M57**), which lies almost halfway between β and γ Lyrae. With a small city-bound telescope, it looks like an out-of-focus star and is fairly bright at about 9th magnitude. With more aperture and magnification, its smoke-ring shape becomes more apparent.

Years ago, friends and I would have contests to see who could find M57 the fastest. With telescopes pointed toward the zenith, the starting gun was fired; the winner had to have M57 in his eyepiece within five seconds. You really have to try hard to see the central star. Around 15th magnitude and surrounded by nebulosity, the star is a challenge for good observers with 16-inch telescopes.

Planetary rings represent stars at the closing stages of their life cycles; our Sun may expel such a cloud in some five billion years. The sky also offers examples of emission nebulae, clouds that are condensing to form new stars. In Sagittarius, the **Lagoon Nebula** (**M8**) and the **Trifid** (**M20**) are stunning exemplars as both are huge stellar birthplaces. Also in Sagittarius is M17, the **Omega Nebula**. Of all the hundred-odd Messier objects, the strange wisps and subtle curls of nebulosity in Omega make this my favorite.

Nebulae dominate the southern skies of summer, but there are not many that are high up for observers in north temperate latitudes. With more experience and a larger telescope, though, objects like **Hubble's Variable Nebula** — one of the sky's true delights — can surprise you. On summer nights you need to catch it early before it sets, but in the winter skies it is more easily visible as a cloud of gas that varies along with, or possibly independently of, its parent star. I first observed this object one evening while comet hunting and got a momentary thrill since it indeed resembles a faint comet. But the familiar conical shape gave its identity away. A large telescope transforms this filmy spot into a convoluted, churning mass of nebulosity.

This summer enjoy all these sights and share the thrill of the Brashears, designers of some of the great telescope lenses of the last century and whose gravestones bear these words:

*"We have loved the stars too fondly
To be fearful of the night."*

Rt. 7, Box 414
Tucson, AZ 85747

The Central Stars of Planetary Nebulae

By David Kratz

Soon after Charles Messier's list of 68 extended objects was published in the almanac "Connaissance des Temps" for 1784, William Herschel proceeded to observe them all with his 11- and 15-inch telescopes. Herschel was quite pleased to discover that he could resolve most of the Messier objects into stars, and also concluded that all of the Milky Way could be resolved into individual stars. Herschel then enlarged the list by discovering over two thousand new objects during the next seven years.

In 1785 Herschel set aside a class of objects that seemed to be observationally distinct from the rest. He called them planetary nebulae, since they vaguely resembled the greenish disk of the planet Uranus, which he had discovered four years earlier. Since Herschel was unable to resolve planetary nebulae into individual stars, he was intrigued by them and continued to investigate their nature. In a paper presented in 1791, Herschel reported an extremely important observation made on November 13, 1790:

"A most singular phenomenon! A star of about 8th magnitude, with a faint luminous atmosphere of a circular form and about 3' in diameter. The star is perfectly in the center, and the atmosphere is so diluted, faint, and equal throughout, that there can be no surmise of its consisting of stars; nor can there be a doubt of the evident connection between the atmosphere and the star. Another star not much less in brightness, and in the same field with

the above, was perfectly free from any such appearance."

With this observation of a gaseous shell apparently associated with a central star, Herschel admitted the existence of "true nebulosity." It would not resolve into component stars. The object was not listed in the Messier Catalogue, but is usually known by its New General Catalogue number, NGC 1514.

Many other planetary nebulae have relatively bright stars located at their centers. Although they differ in observational detail, planetaries possess a similar morphology that places them into a distinct class. Planetary nebulae tend to be symmetric, at least about one axis, and there is nearly always a star at a centrally located position. In 1864 William Huggins examined the planetary nebula NGC 6543 with a spectroscope and found an emission-line spectrum. This indicated that the nebula was composed of a hot, thin, luminous gas rather than a mass of unresolved faint stars. Herschel had not only correctly categorized planetary nebulae into a single class but also correctly interpreted their nature.

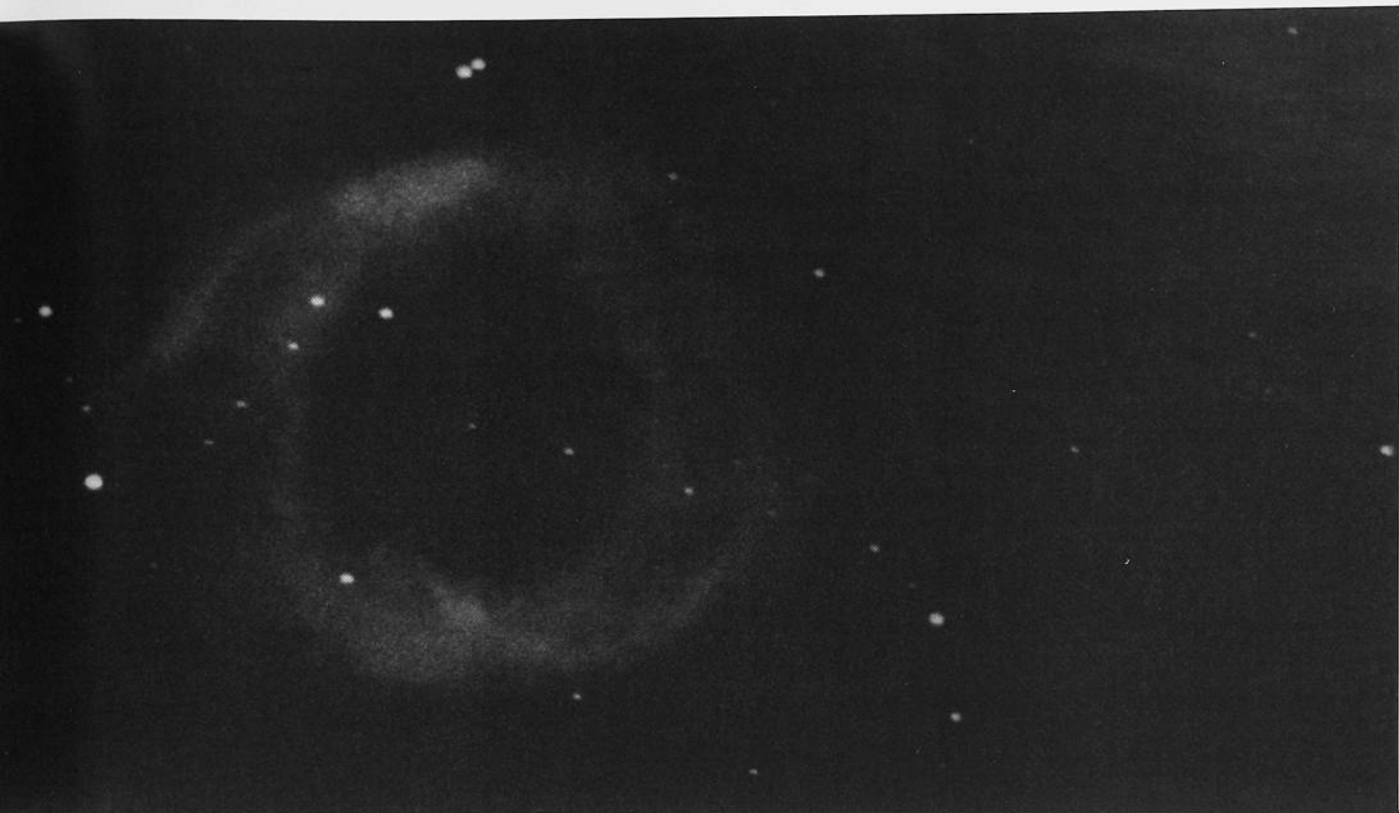
Since Huggins' time, astronomers have employed spectroscopy to determine the nature of a variety of celestial objects. For the case of a planetary nebula whose spectrum consists of both line and continuum emissions, the spectrum indicates the physical condition within the nebula, especially the electron density and temperature, the abundance of various

elements, and the radiation field of the exciting star. The spectrum of a planetary nebula also yields information on the nebula's radial velocity.

The Progenitors of Planetary Nebulae

In order to gain a full understanding of planetary nebulae, we must look at the nature of their central stars. This is a relatively recent and complex field due to the faintness of these stars. These post-asymptotic giant branch or pre-white dwarf stars (depending upon one's point of view) are not as well understood as their nebular progeny. Often the light from the surrounding nebulosity is such an overwhelming contaminant that observation of the central star is difficult: measurements are uncertain, and in some instances the central star is completely hidden by nebulosity. A clear view of a planetary's central star is usually a result of the advancing age and size of the surrounding nebulosity. However, the central star will also be well along in its evolution and is frequently intrinsically faint. This obviously leads to problems with observational selection, requiring astronomers to consider biases in the interpretation of the data.

The most important fundamental data for the central stars are their absolute magnitudes, which are used to determine both temperature and luminosity. Unfortunately, absolute magnitudes are the least certain of the fundamental data. The problem, of course, is light from the nebulosity itself, which makes the central stars seem brighter than they actually are. The most



reliable magnitudes are those for low surface brightness nebulae and those for which the light of the nebula has been quantitatively taken into account.

The effective temperature and the luminosity of the central star taken together determine its location on the Hertzsprung-Russell diagram, which in turn yields information about the star's evolution. From extensive analysis it has been determined that the effective temperatures of central stars range from 25,000 K (the minimum needed to ionize a nebula) to 150,000 K. Although certain stars may well exceed the upper effective temperature, there is no substantiated proof that they do.

How Planetary Nebulae Might Evolve

For the first 90% of its lifetime a main sequence star of moderately low mass (less than about six solar masses) converts hydrogen into helium in its central regions. In the course of this conversion, the outer layers of the star expand, cool, then gravitationally contract. This contraction "squeezes" the stellar material, causing the core to heat up again—thereby increasing the hydrogen burning rate. The balance between a star's expansion and contraction is called hydrostatic equilibrium and is responsible for maintaining the star's temperature, pressure, and density for the majority of its lifetime.

Eventually, when the hydrogen fuel in the core is exhausted, the core ceases to release enough nuclear energy to support the star's mass and it slowly begins to contract, releasing

gravitational energy. As this happens, the hydrogen that is somewhat farther away from the center begins to burn, producing a hydrogen-burning shell, which surrounds a helium core. A dramatic change occurs when the nearly isothermal core contains about 10% of the mass of the star. The slowly contracting isothermal core is unable to support the outer regions of the star and rapidly collapses. Simultaneous with the core collapse is the expansion of the star's envelope. The star becomes a red giant.

For stars with less than 2.25 solar masses, the core density becomes so high that the gas no longer adheres to the ideal gas law. It becomes degenerate and the pressure and internal energy of the gas essentially becomes independent of temperature. As a result, the contracting core increases in temperature due to the release of gravitational energy. Eventually, the core becomes so hot and dense that the helium in it ignites. This results in an increased energy production and a still higher temperature. But since the stellar matter is degenerate (a densely-packed mass composed of atomic nuclei and free electrons that exert a quantum pressure called degeneracy pressure), it does not expand and therefore there is no reduction in the rate of energy production.

This process continues until the temperature becomes so high that the degeneracy is lifted and the central region of the star expands explosively.

The Helix Nebula's central star is difficult to observe and requires good seeing conditions. Note the faint outer shell in this photo taken through a 17.5-inch f/4.5 reflector using a Lumicon Deep-Sky Filter, Fuji 400 film, and a 53-minute exposure. All photos by Jack Marling.

This thermal runaway is known as the "helium flash." The star now has a new energy source in the form of burning helium and achieves a temporary stability after a rapid internal readjustment, including contraction of the outer envelope. The star is now on the horizontal branch of the H-R diagram. (For stars more massive than 2.25 solar masses the electron gas in the core does not become degenerate before the helium is ignited and therefore the transition to helium core burning is more quiescent.)

After a period of time relatively short compared to its main sequence lifetime, the majority of helium in the core is fused into a carbon-oxygen core. This new core, containing highly degenerate electrons, contracts and heats rapidly, thereby releasing gravitational energy. As before, the envelope simultaneously expands dramatically. This giant star, which contains an inert carbon-oxygen core, is called an asymptotic giant branch star.

Following the carbon-oxygen core contraction and the subsequent rapid rise of core temperature, the helium-burning shell becomes less massive but more luminous, and the hydrogen-

burning shell ceases temporarily. The helium-burning shell, however, is thermally unstable. A small increase in temperature will result in a thermonuclear runaway, reminiscent of the helium core flash, and is referred to as the helium shell flash. After the thermonuclear runaway terminates, the helium-burning shell continues burning quiescently until it has exhausted the supply of helium whereupon the hydrogen-burning shell is renewed. When the mass of the helium-rich region left behind by the advancing hydrogen-burning shell reaches a critical value, the helium-burning shell is re-ignited and the whole process begins again. The entire process — from the contraction of the carbon-oxygen core to the re-ignition of the helium shell — is called a pulse. The interval between pulses depends upon the mass of the carbon-oxygen core and may vary from thirty years for a 1.4-solar mass core to several thousand years for a less massive core.

Unfortunately, the evolutionary track that an asymptotic giant branch star follows to the planetary nebula phase is not well known. There are, however, two compelling reasons to believe that an asymptotic giant branch star is the immediate precursor of planetary nebula.

First, a red giant that has ascended to the top of the asymptotic giant branch possesses physical similarities to a planetary nebula. The degenerate carbon-oxygen core has a mass and size reminiscent of the central star of a planetary nebula and therefore, if the star's envelope were removed, the core would become the central star while the envelope would become the nebula.

The second reason is more deterministic and is based upon the expansion velocities of planetary nebulae. In order to escape the gravitational field of a star, a nebula requires a minimum radial velocity. The resultant expansion velocity of the nebula is determined from the difference between its initial radial velocity and the velocity of escape. The observed expansion velocities of planetary nebulae lie in the narrow range between 10 km/sec and 40 km/sec, and therefore the escape velocity must be comparable to the observed expansion velocities. The escape velocity for white dwarfs or even main sequence stars is much higher than these values. Only a red giant of 100 to 200 solar radii can satisfy these conditions.

It has been observationally established that asymptotic giant branch stars do indeed lose mass, typically on the order of 10^{-7} to 10^{-6} solar masses per year. The existence of planetary nebulae though, requires a mass-loss rate well in excess of 10^{-5} solar

masses per year. This high mass-loss rate is sometimes called the "superwind" and is capable of removing most of the envelope of the asymptotic giant branch star on a comparatively short time scale. The origin of the superwind has not yet been determined, although it is probably related to pulsational instabilities in the outer atmosphere of the star.

Near the end of the superwind phase the remnant envelope mass becomes very small and the star departs from the asymptotic giant branch. The stellar remnant contracts and the superwind ceases. The central star now consists of a degenerate carbon-oxygen core surrounded by a low mass hydrogen-rich envelope. The star becomes smaller and hotter as matter from the envelope is burnt within the shell sources and flows into the core. When an effective temperature of 25,000 K is attained, the central star can ionize the surrounding nebula, and the planetary nebula becomes visible.

The timescale of the subsequent evolution of the central star is determined by the rate at which the fuel remaining in the envelope is consumed. Once the fuel is exhausted the central star radiates away light at the expense of its temperature and it becomes a white dwarf. After only a few tens of thousands of years the nebula expands into obscurity, leaving only the white dwarf.

Observing Planetary Nebulae

Even though planetary nebulae are relatively ephemeral, they can often be rather spectacular in appearance. As discussed in "Observing Planetary Nebulae" (Deep Sky 6, Spring 1984) there are about 100 of these objects that are visible to the amateur astronomer with a modest sized telescope. But the number of planetary nebulae with visible central stars is probably only a quarter of the above total. Some central stars, though, visually dominate the associated nebulosity. NGC 1514 is an example. Indeed, there are examples where the central star is easy, like ninth-magnitude FG Sagittae, though the nebula is exceedingly faint. The other extreme is NGC 7027, a small but reasonably bright and easy object whose central star has never been observed.

Some of the techniques used to find and observe planetary nebulae must be modified when attempting to view the central star of a planetary nebula. The use of narrow bandpass nebular filters, which exploit fact that planetary nebulae possess emission line spectra, increases the contrast between the nebula and the background skylight. Moreover, starlight is also diminished by the nebula filter, a very useful thing to remember when attempting to identify small planetary nebulae. The problem

with employing a nebular filter is that the light from the central star will also be filtered out, sometimes to the point of rendering an otherwise visible central star invisible.

The use of a prism or replica diffraction grating, on the other hand, results in the spectrum of the central star projecting through the nebula's spectrum. On other nebulae, however, a prism produces a composite spectrum, the result of the central star having an emission line spectrum different from the spectrum of the nebulosity.

When the light from the central star dominates the light from the nebula, averted vision can be employed to bring out the nebula. The reverse, although not quite as successful, can also be employed to bring out a central star hidden in the nebula's haze. High power can also be employed to reduce the nebula's relative surface brightness, often revealing the central star.

NGC 40. Located approximately one third of the way from Gamma Cephei to Gamma Cassiopeiae, NGC 40 is a fine example of a planetary nebula with a comparatively bright central star. The nebula is a fairly uniformly luminous disk approximately 37" in diameter. The central star, which is magnitude 11.6, is easily visible in a 6-inch telescope. The central star is also very rich in bright emission lines and should display a beaded appearance through a prism.

NGC 246. A large planetary nebula in the constellation of Cetus, NGC 246 forms the southern vertex of an equilateral triangle, 1.5 degrees on a side, with the stars Phi (ϕ) 1 and Phi (ϕ) 2 Ceti. In good seeing, the planetary exhibits a non-uniform annulus some 4' in size. Though the 12th-magnitude central star is faint, the entire object does not suffer from a high nebular surface brightness like some.

NGC 1360. An often overlooked planetary nebula in the constellation of Fornax, NGC 1360 is located approximately 10° north of the Fornax cluster of galaxies. The overall magnitude and angular size of NGC 1360 are nearly the same as the Dumbbell Nebula (M27). In an 8-inch telescope, NGC 1360 is a large diffuse north-south-oriented oval nebulosity, nearly 6' across, containing a faint central star.

NGC 1514. As noted before, the observation of this planetary in the fall of 1790 led William Herschel to the conclusion that "true nebulosities"

Exhibiting its distinctive hourglass shape in this photo taken with the University of Hawaii's 24-inch reflector at f/9, the Dumbbell Nebula in Vulpecula is a bright planetary in small telescopes. The central star, at nearly 14th magnitude, is more elusive and requires high power and a dark sky.



existed. Located near the Taurus-Perseus border, NGC 1514 is a very faint circular nebula approximately 3' in diameter dominated by a ninth-magnitude central star. The star, as it turns out, is actually a binary comprising an AO III star and a blue subdwarf. It is the very faint blue subdwarf that excites the nebula. The period of the system is 0.41 days.

NGC 1535. Located approximately 1 degree north and 4 degrees east of Gamma (γ) Eridani, this rather small (18"/44") but bright planetary contains a 12th-magnitude central star. Located in a somewhat sparse field, this distinctly bluish object is best found by scanning 2.5° due south of 39 Eridani.

IC 418. Located one hour and thirteen minutes virtually due east of NGC 1535, IC 418 forms an isosceles triangle with Rigel (5.5° to the north northwest) and Saiph (5.5 degrees to the east northeast). Fairly small (12"), IC 418 possesses a fairly high surface brightness and a very bright central star. While stellar at low power, this object has an annular appearance in larger telescopes. The central star is a spectroscopic binary with a period of 0.2 days.

IC 2149. Even though this planetary nebula is quite small (8"), it is easy to locate, for two 6th-magnitude stars, near Pi (π) Aurigae, point right toward this object. Slightly bluish in color, IC 2149 is quite elongated and has a fairly high surface brightness. The central star's magnitude is comparable to the nebula's magnitude and is more easily viewed at high power.

NGC 2346. This very interesting 13th-magnitude planetary nebula is approximately one minute in angular size and slightly elongated in the north-south direction. The central star is an eclipsing binary with a period of around 17.2 days and varies in brightness from 11.3 to 13.4. At maximum the central star far outshines the surrounding nebulosity; however, at minimum the central star can be difficult to detect. The shape of the light curve indicates that the components are very close, perhaps semi-detached. The spectral type of the visible star is thought to be A5 V, too cool for it to be exciting the nebula. The shift in its color index during eclipses indicates that the companion is even cooler; therefore a third star is felt to be present to cause the nebula to fluoresce. Located in a fine field of view 0.7° west southwest of Delta Monocerotis, NGC 2346 has somehow evaded inclusion in the *Skalnate Pleso*, the *Sky Atlas 2000.0*, and the *AAVSO Variable Star Atlas* even though it was discovered by William Herschel.

NGC 3132. Located on the Vela side on the Vela-Antila border, this object rivals the Ring Nebula in both size and brightness. Called the Eight-Burst

Nebula for its complex appearance in photographs, NGC 3132 possesses a prominent central star. Its spectral type of A2 V, however, indicates that this star is not responsible for the luminescence of the nebula. In fact, the actual central star is a blue subdwarf 1.6" from its brighter component and of magnitude 16.

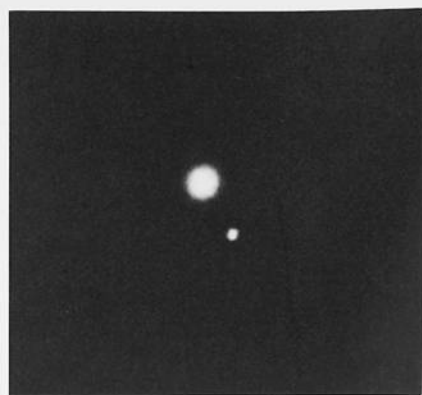
NGC 3242. This very fine planetary nebula is located approximately 1.8° south of Mu (μ) Hydrae. Distinctly blue in color, NGC 3242 is a 16" oval, a size reminiscent of Jupiter, hence this softly glowing 9th-magnitude disk is often referred to as "The Ghost of Jupiter." Even though the central star is rated at 12th magnitude, it is quite difficult because of the high surface brightness of the nebula.

IC 3568. Located in Camelopardalis 1° southwest of a fifth magnitude double star, this planetary nebula is a 6-arcsecond, magnitude 11.5 fuzzball. A 12th-magnitude star located to the west-southwest makes a good comparison object, while the central star makes its presence known at moderate power. At a declination of 82.5° north, IC 3568 is the northernmost known planetary nebula.

NGC 6543. One of my favorite objects, this planetary has a declination high enough to keep it visible year-round for most northern observers. NGC 6543 is located 0.5° northeast from a 7th-magnitude star 9.5° north of Xi (ξ) Draconis. This magnitude 8.8 planetary has a very high surface brightness and a distinctly bluish-green color. An 18" oval elongated on a north-south axis, NGC 6543 is surrounded by a very faint wreath of material nearly 6' in diameter and beyond the capability of many backyard instruments. The central star is somewhat difficult to see due to the high surface brightness of the nebulosity. Oddly enough, I have found that unlike nearly every other planetary, the central star of NGC 6543 is easiest to view at low power.

NGC 6572. Found in the northeast corner of Ophiuchus, NGC 6572 is very small, fairly bright and rather bluish. Elongated north to south, and 8" in diameter, this planetary contains a somewhat difficult 13th-magnitude central star. Again the relatively high surface brightness of the nebula makes observing the faint central star a challenge.

NGC 6720. The Ring Nebula (M57), located 40% of the way from Beta (β) Lyrae to Gamma (γ) Lyrae, is probably the best known and most widely observed of the planetary nebulae. Found in 1779 by Antoine Darquier, the Ring Nebula clearly has an annular appearance in a 6-inch telescope. An 8-inch telescope, under good sky conditions, reveals that the central hole is not empty but filled with a faint ghostly



Above: IC 3568 in Camelopardalis is a small planetary with a 12th-magnitude central star. Below: NGC 7009 (Saturn Nebula) in Aquarius. Both photographs were taken using the University of Hawaii's 24-inch reflector at f/15.



fluorescence. Unfortunately, a 14-inch or larger telescope is required to show the Ring Nebula's 14th-magnitude central star. This star possesses a continuum spectrum and a temperature in excess of 100,000 K.

BD +30° 3639. Located approximately 1° north of 9 Cygni, this object is charted on Wil Tirion's *Sky Atlas 2000.0* but is not identified. The rather strange designation merely refers to the *Bonner Durchmusterung* catalogue of 1903 and the object's declination. Discovered by W. W. Campbell at Lick Observatory in 1893 (and often referred to as Campbell's Star), this object is a very small (8") planetary of about 10th magnitude. It has a high surface brightness and exhibits a slight bluish tinge. As with other nearly stellar planetary nebula, a nebular filter will aid in identification. However, the effect of the nebular filter will not be as pronounced as with other planetary nebulae. This is because a substantial amount of light we receive from this object originates from the central star, which is a Wolf-Rayet star similar to NGC 40's central star. Therefore a prism may prove useful in separating the central star from its associated nebulosity.

NGC 6826. About 30" in diameter, this planetary possesses a moderate

Planetaries with Prominent Central Stars

Object	R.A.(2000) Dec.	Con.	Mag.	Mag.*	Diam.	Spectral Type
NGC 40	00h13.0m +72° 32'	Cep	10.7	11.61	37"	WC8
NGC 246	00h47.0m -77°53'	Cet	8.0	11.94	225"	OVI+K
NGC 1360	03h33.3m -25°51'	For	7.0	11.35	390"	sdO
NGC 1514	04h09.2m +30°47'	Tau	10.8	9.40	114"	AOIII+sdO
NGC 1535	04h14.2m -12°44'	Eri	9.6	12.24	18"/44"	O5
IC 418	05h27.5m -12°42'	Lep	10.7	10.65v?	12"	O7f
IC 2149	05h56.3m +46°07'	Aur	11.2	11.59	8"	O7.5
NGC 2346	07h09.4m -00°48'	Mon	12.5	11.16v	55"	A5V
NGC 2392	07h29.2m +20°55'	Gem	9.9	10.47	13"/44"	O7f
NGC 3132	10h07.7m -40°26'	Vel	8.2	10.07	47"	A2V+sdO
NGC 3242	10h24.8m -18°38'	Hya	8.6	12.00	16"/1250"	cont.
IC 3568	12h32.9m +82°33'	Cam	11.6	12.31	6"	O5f
NGC 6543	17h58.6m +66°38'	Dra	8.8	11.44	18"/350"	of+WR
NGC 6572	18h12.1m +06°51'	Oph	9.0	13.60	8"	of+WR
NGC 6720 (M57)	18h53.6m +33°02'	Lyr	9.7	14.80	70"/150"	Cont
BD+30° 3639	19h34.8m +30°31'	Cyg	9.6	10.03	8"	WC9
NGC 6826	19h44.8m +50°31'	Cyg	9.8	10.44	30"/140"	O6fp
NGC 6853 (M27)	19h59.6m +22°43'	Vul	7.6	13.94	350"/910"	O7
NGC 7009	21h04.2m -11°22'	Aqr	8.3	11.50	25"/100"	Cont
NGC 7027	21h07.1m +42°14'	Cyg	10.4	11.3B?	15"	?
NGC 7293	22h29.6m -20°48'	Aqr	6.3	13.47	769"	sdO

Mag. = nebular photographic magnitude

Mag.* = V magnitude of central star

surface brightness and a dominant central star. Direct viewing shows a 10th-magnitude star surrounded by a faint circular nebulosity. With averted vision, the nebula is much more prominent. For this reason, NGC 6826 is popularly referred to as "The Blinking Planetary." Located approximately 0.5° east of the 6th-magnitude double star 16 Cygni, this object is surrounded by a thin wreath of material about 2' in diameter.

NGC 6853. The Dumbbell Nebula (M27) is probably the most conspicuous planetary nebula in the entire sky. Bright and easy to find, M27 is located 0.4° south of the middle star in the "M" of Vulpecula, which is formed from the stars 12, 13, 14, 16, and 17 Vulpeculae. Normally the dumbbell shape is best seen with small telescopes. A 6-inch may reveal the central star on a night of good transparency, but it will be easier to see if very high power is used. With a temperature in excess of 130,000 K, the central star of M27 is one of the hottest known.

NGC 7009. The Saturn Nebula is among the easiest of the planetary nebulae to locate, as it lies just over one degree west of the naked-eye star Nu (ν) Aquarii. Possessing a magnitude of 8.3 and a relatively small angular size

(25"), NGC 7009 has one of the highest surface brightnesses of any of the planetaries. Unfortunately small telescopes are unable to show the complex structure which gives this object its name. Its greenish blue oval is unmistakable. The high surface brightness also swamps out the central star and makes it much more difficult to view than its rated magnitude would suggest.

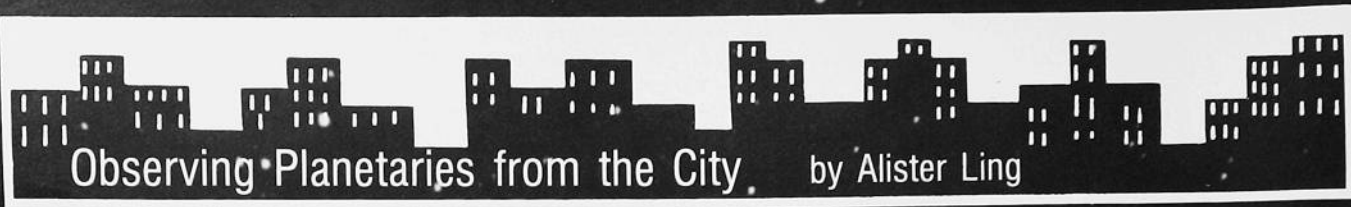
NGC 7027. The nature of this object is often debated and it is sometimes not included in lists of planetary nebulae. The reason is that the central star has never been observed and must possess a magnitude fainter than 17. The luminosity, however, possesses all the properties of a classic planetary, and is often used to study nebular properties because the data is not contaminated by light from a central star. Information from the nebula indicates that the central star is exceedingly hot, a temperature as high as half a million degrees Kelvin has not been dismissed. Such a high temperature would, of course, force the peak of the Planck curve far into the ultraviolet (around 50 Angstroms), and hence very little energy would be available from the star in the form of visible light. Located approximately two° south of Xi (ξ) Cygni, NGC 7027 is a small (15"), bright

(magnitude 10.4), high surface-brightness, bluish planetary.

NGC 7293. The Helix Nebula in Aquarius is the largest planetary nebula in the sky, but it is also one of the more difficult to see because of its low surface brightness. Through a telescope or binoculars it resembles a large ghostly wreath nearly 13' across. Averted vision will prove helpful, haze will prove disastrous. The 13th-magnitude central star is quite difficult; though, under good sky conditions, a 6-inch telescope might show it.

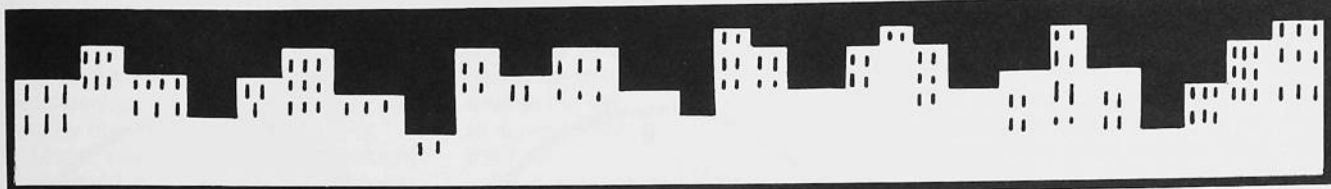
Planetary nebulae come in a variety of shapes, sizes, and brightnesses, all of which are determined by the fate of their progenitor stars. Take some time this summer to survey a variety of planetaries and accompanying central stars; you'll be amazed that some are faint, others easy, but all are enjoyable and relaxing to hunt down.

David Kratz has a Master's degree in astronomy and is currently a graduate student at SUNY in Stony Brook, N.Y. His last article, "Observing Planetary Nebulae," appeared in the Spring 1984 issue of *Deep Sky*.



Observing Planetaries from the City by Alister Ling





For those of us who live in thriving metropolises, a dark site can be quite far away. And on many occasions, an all-night observing session isn't possible — be it family considerations, a weeknight, or simply the Full Moon getting in the way. But don't despair — there are dozens of glowing planetary nebulae that because of their small diameters and high surface brightnesses are not overly affected by light pollution. Many of these are visible even in small scopes.

There are a number of advantages behind this type of observing. First and foremost, it allows you to step outside for just an hour or two and then retreat back inside, which is especially convenient in winter! Second, it makes a nice introduction to a class of objects that you probably would not observe under darker skies. And third, it helps to improve your observing techniques insofar as dealing with small details or indistinct forms. Generally speaking, it satisfies the craving built up by cloudy New Moons, clear Full Moons, and life in general.

How must we adapt our observing techniques to meet the antagonistic nature of our bright environment? One has to overcome the physical problems. For instance, build a screen to combat direct streetlight or moonlight (a cloak can come in handy here), and place boards around an apartment balcony to prevent eyepieces from rolling off your tenth-floor observing platform. A clock drive is also very useful when one is probing a nebula at powers over 200x.

Sky-wise, planetaries are distributed mainly along the Milky Way where there are hoards of 8th- and 9th-magnitude stars. A detailed atlas, such as the *Variable Star Atlas of the American Association of Variable Star Observers* or the *Smithsonian Astrophysical Observatory Star Atlas* with its larger scale and fainter stars, is indispensable in searching for one's quarry.

If you've located your target, you're set. But let's assume for the moment that this is not so: you have the right field and the nebula you're looking for is supposed to be bright. How can you tell which star is the planetary? A careful examination of each possible candidate at high power may reveal a tiny disk. This is where high-quality optics come into play. If you own a short focal-length telescope such as an f/4, try a cardboard screen with a hole placed such that the aperture is unobstructed by the spider vanes. This should give your

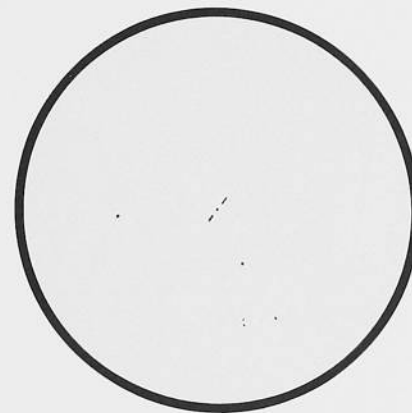
scope refractor-like performance.

Turbulence can be a big problem in cities, especially if your line of sight passes over a tarmac or a house because the heat released from them at night can be phenomenal. "Stellar" planetaries may be detected in the

NGC 7026
14-inch SCT
370x



Campbell's Star
14-inch SCT
110x



same manner that planets are distinguished from the brighter stars: their disks, though small, are larger than a mere point so that when the images are moved by a turbulent cell they are displaced by only a fraction of their width, causing but a small change in brightness. The stars, however, get displaced by more than their Airy disks so they fluctuate more visibly. Simply put, small planetaries should look "flat" compared to neighboring stars. On occasion, a green or blue color can tip you off as to which star is the target.

When the above fails, you can resort to more modern techniques. The principal property that distinguishes emission nebulae from stars and other deep-sky objects is their spectra. The light is created by the recombination of electrons and ionized oxygen, nitrogen, and a handful of other atoms. Fortunately, the color is severely limited to small regions in the blue and mainly in the green, the latter being the color to which the eye is most sensitive.

Because of these properties, one can use a prism, diffraction grating, or nebular filter to isolate particular emission lines from the continuous spectra of the surrounding stars. Both the prism and diffraction grating achieve the same result of spreading out the starfield into a myriad of spectra, leaving the planetary as a spot source. Using a prism at the eyepiece can be awkward, so I suggest using a cheap replica grating of the transmission type. These may be purchased from scientific equipment houses (such as Edmund Scientific Co.) for a couple of dollars.

Nebular filters, though more expensive than the prism or grating types, offer another important advantage: they guarantee a dark sky. By suppressing all wavelengths except those primarily emitted by nebulae, the filter allows the light from the planetary to pass while dimming that of the surrounding stars and the sky. Consequently, contrast is improved and the planetary seems to brighten with respect to the stars. Gratings or prisms won't do this. Passing the filter back and forth between the eyepiece and your eye (called the "flicker test") should make detection of the stubbornest planetaries easier.

Stellar Planetaries

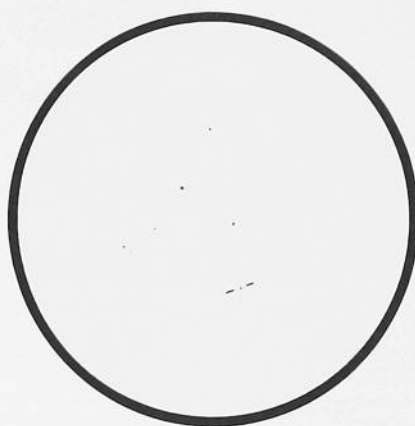
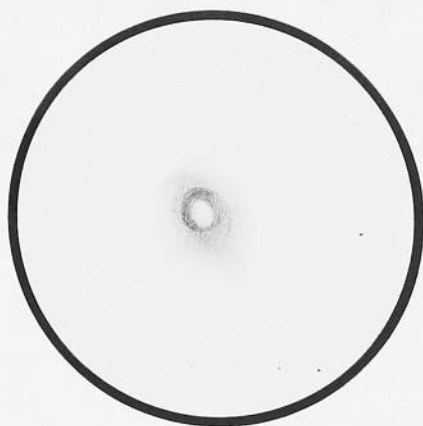
Planetaries smaller than 5" abound in the heavens. Both *DSM #6* and the Webb Society's *Deep-Sky Observer's Handbook Vol. 2* contain extensive lists of these objects. Campbell's star (BD +30 3639) in Cygnus is a good representative of this class. At magnitude 9.6 it is a bright object, but detecting its 3" disk requires a sharp eye. At 110x, you should be able to locate and easily confirm the nebula by the flicker test. Moving in at 370x, it should appear nonstellar and round. A "suspected" nebula is often confirmed later, so don't hesitate to take notes or make a sketch to compare with other observations.

When the air is turbulent, all detail is wiped out so you must wait for a more favorable time to make a positive

NGC 1535
14-inch SCT
370x

IC 4846
14-inch SCT
110x

NGC 6894
14-inch SCT
110x



All sketches by Alister Ling

Planetary Nebulae Visible From Cities

Object	R.A. (2000) Dec.	Con.	Mag.	Mag.*	Diam.	Filter Required?
NGC 40	0h13.0m +72°32'	Cep	10.7	11.61	37"	Likely
NGC 650-51 (M76)	1h42.4m +51°34'	Per	12.2	17.0	65"/290"	Yes
IC 1747	1h57.6m +63°20'	Cas	13.6	14.54	13"	Yes
IC 351	3h47.5m +35°03'	Per	12.4	14.77	7"	Flicker
IC 2003	3h56.4m +35°52'	Per	12.6	16.49v?	7"	No
NGC 1501	4h07.0m +60°55'	Cam	13.3	14.39	52"	Yes
Minkowski 2-2	4h13.3m +56°57'	Cam	—	—	12"	Yes
NGC 1535	4h14.2m -12°44'	Eri	9.6	12.4	18"/44"	No
Jonckheere 320	5h05.6m +10°42'	Ori	12.9	14.4	11"	Flicker
IC 418	5h27.5m -12°42'	Lep	10.7	10.65v?	12"	No
NGC 2022	5h42.1m +09°05'	Ori	12.4	15.20	18"	No
IC 2149	5h56.3m +46°07'	Aur	11.2	11.59	8"	No
Jonckheere 900	6h26.0m +17°47'	Gem	12.4	15.3	12"	No
NGC 2371/72	7h25.6m +29°29'	Gem	13.0	15.5	55"	Yes
NGC 2392	7h29.2m +20°55'	Gem	9.9	10.47	13"/44"	No
NGC 2438	7h41.8m -14°44'	Pup	10.1	17.7	66"	Yes
NGC 2440	7h41.9m -18°13'	Pup	19.1p	—	14"/32"	No
NGC 2610	8h33.4m -16°09'	Hya	13.6	15.5v?	37"	Yes
NGC 3242	10h24.8m -18°38'	Hya	8.6	12.0	16"/1,250"	No
NGC 3587 (M97)	11h14.8m +55°01'	UMa	12.0	15.88	194"	—
IC 4593	16h12.2m +12°04'	Her	10.9	11.27	12"/120"	No
Abell 39	16h27.5m +27°54'	Her	12.9	15.8	170"	Yes
NGC 6210	16h44.5m +23°49'	Her	9.3	12.90	14"	No
NGC 6309	17h14.1m -12°55'	Oph	10.8	14.4	14"/66"	No
NGC 6445	17h49.2m -20°01'	Sgr	13.2	19.1b	34"	No
NGC 6572	18h12.1m + 6°51'	Oph	9.0	13.6	8"	No
NGC 6567	18h13.7m -19°05'	Sgr	11.7	15.0b	8"	Yes
Humason 2-1	18h49.8m +20°50'	Her	11.6	13.3	3"	Yes
NGC 6720 (M57)	18h53.6m +33°02'	Lyr	9.7	14.8	70"/150"	No
IC 1295	18h54.6m -08°50'	Sct	15.0	15p	86"	Yes
NGC 6741	19h02.6m -00°27'	Aql	10.8	14.7	6"	Flicker
NGC 6751	19h05.9m -06°00'	Aql	12.5	13.89	20"	Yes
NGC 6772	19h14.6m -02°42'	Aql	14.2	18.4b	62"	Likely
IC 4846	19h16.5m -09°03'	Aql	12.7	13.7v	—	Flicker
NGC 6778	19h18.4m -01°36'	Aql	13.3	15.0b	16"	No
NGC 6781	19h18.4m +06°33'	Aql	13.3	15.0b	16"	Likely
NGC 6790	19h23.2m +01°31'	Aql	10.2	13.53	7"	No
NGC 6803	19h31.3m +10°03'	Aql	11.3	15.2	6"	Flicker
NGC 6804	19h31.6 +09°13'	Aql	12.2	14.23	31"/66"	Likely
NGC 6807	19h34.6m +05°41'	Aql	13.8	13.97	—	Flicker
BD 30°+3639	19h34.8m +30°31'	Cyg	9.6	10.0	8"	Flicker
NGC 6826	19h44.8 +50°31'	Cyg	9.8	10.44	30"/140"	No
NGC 6842	19h55.0m +29°17'	Vul	13.6	15.98	50"	Yes
NGC 6853 (M27)	19h59.6m +22°43'	Vul	7.6	13.94	350"/910"	Yes
NGC 6857	20h01.8m +33°31'	Cyg	11.4	13.3	40"	—
NGC 6884	20h10.4m +46°28'	Cyg	12.6	15.6	6"	Flicker
NGC 6891	20h15.2m +12°42'	Del	11.7	12.41	12"/74"	No
NGC 6894	20h16.4m +30°34'	Cyg	14.4	15.8v?	42"	Yes
NGC 6905	20h22.4m +20°07'	Del	11.9	13.5b	46"/100"	No
NGC 7008	21h00.6m +54°33'	Cyg	13.3	13.21	83"	Likely
NGC 7009	21h04.2m -11°22'	Aqr	8.3	11.5	25"/100"	Maybe
NGC 7026	21h06.3m +47°51'	Cyg	12.7	14.50	21"	No
NGC 7027	21h07.1m +42°14'	Cyg	10.4	11.3b	15"	No
NGC 7048	21h14.2m +46°16'	Cyg	11.3	18.3b	61"	Likely
NGC 7094	21h36.9m +12°47'	Peg	—	13.60	95"	—
NGC 7139	21h45.9m +63°39'	Cep	13	18.1b	78"	—
NGC 7293	22h29.6m -20°48'	Aqr	6.5	14.09	769"	—
NGC 7354	22h40.4m +61°17'	Cep	12.9	15.0	20"	—
IC 1454	22h42.6m +80°27'	Cep	14.8	16.4	33"	—
NGC 7662	23h25.9m +42°33'	And	9.2	13.17v?	20"/130"	No

Notes: Mag* = Visual photoelectric magnitude of central star, B = photoelectric blue value, v = variable central star.

identification. Such was the case for IC 4846, a 12.7-magnitude 2" speck in Aquila. Without the flicker test, I could not detect any difference between it and nearby stars.

Under steadier conditions, I thought I glimpsed fuzzy edges to the stellar NGC 6807, also in Aquila and only 2" across.

Remember that these planetaries are roughly the same size or smaller than the apparent disk of Uranus, so don't expect to see too much detail.

Visible Detail

With planetaries that are as large as the apparent disk of Saturn, we can begin to discern some detail. Even at low power, the 20" x 17" 10.8-magnitude disk of NGC 1535 in Eridanus is evident without a filter. I observed an undefined outer halo, elongated in p.a. 45°, surrounding a

NGC 6894

brighter, slightly fuzzy inner annulus. At 370x in a 14-inch SCT, I also noted a darker center. With a nebular filter I missed the central star, so don't forget to compare the view with and without the filter.

Another interesting object, though not a planetary, was originally classified as one. Discovered by Webb himself in 1879, NGC 7027 is 18" x 11" in p.a. 135° and shines at magnitude 10.4 in Cygnus. Even two days before the Full Moon from a downtown location, the 14-inch SCT showed it having a very green hue through a filter. At 370x, I noted the central star just off to the northwest side. With direct vision, I had the impression that the star was not stellar. In addition, the northwest side of the nebula seemed brighter. A drawing of NGC 7027 as viewed through a 98-inch scope appears on

Jack B. Marling

page 125 of the Webb Society's Handbook.

Nearby is NGC 7026, a magnitude 11.8 planetary measuring 28" x 13". Once again, under a nearly Full Moon I saw a dark lane running north and south. With direct vision, I thought I saw a star attached to the following edge. The preceding edge was, on the whole, brighter.

Apart from visibility of the central star, what else should one look for? The rest of the nebula is equally important. Here are some questions you should ask yourself while observing: Are the edges sharp or do they fade? If they fade, how quickly? Are the edges evenly bright all the way around? How does the appearance change when direct vision is used? What effect does the filter have apart from making the planetary brighter? And try using as high a power as possible from time to time if the seeing permits — you may be surprised!

Large Nebulae

There are a fair number of Jupiter-sized planetaries that have relatively high surface brightnesses and can also be seen from urban areas, too. Except for M97 (which has a very low surface brightness), the Messier planetaries provide interesting views, especially M76. The two patches of this nebula are not quite in contact, and one section is definitely brighter than the other. Can you tell which? Direct vision may be helpful here.

At first, I never bothered to locate the larger NGC's simply because I assumed they would be too difficult. When I looked for NGC 6894 in Cygnus (42" in diameter and magnitude 14.4), I had forgotten how difficult an object it was under dark skies (with no filter) in a 10-inch f/4.1. However, with a filter, the 14-inch SCT just barely managed the feat. At high power, this planetary simply disappeared. It just goes to show that you'll never know what you're missing unless you try.

From a small city (a quarter of a million people), I located the supposedly difficult IC 1295 in Scutum (86" in diameter and magnitude 15) without effort in a 12.5-inch f/5.6. This would, of course, have been impossible without the use of a nebular filter. The more specialized filters such as the UHC and O-III types from Lumicon allow one to cut out everything except the glow from a few green emission lines. This intense screening can dim stars up to three magnitudes without harming the nebula, thus increasing the usefulness of the flicker test. I am sure that comparisons between the different filters can turn up structures never before seen.

The possibilities of making serious observations of planetary nebulae from the city appear almost unbounded. Armed with a nebular filter, one should have a few year's work ahead.



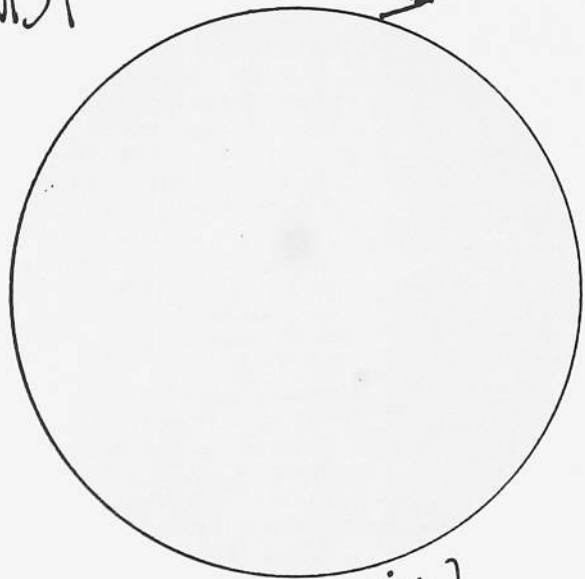
Deep Sky Sketchbook

This book's sketchbook features drawings from Tom Sarna, of Downers Grove, Illinois. Tom is an avid observer and the author of the "Sarna Deep Sky Atlas", a collection of detailed finder charts.

Yours Truly,
D. Eider

M51

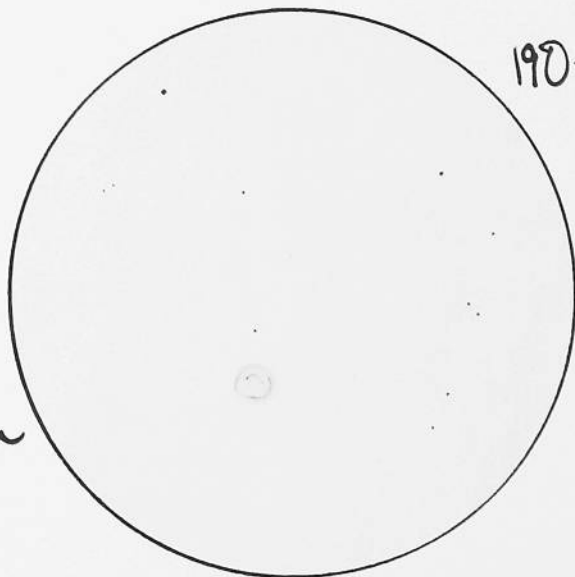
The Whirlpool.



low power view

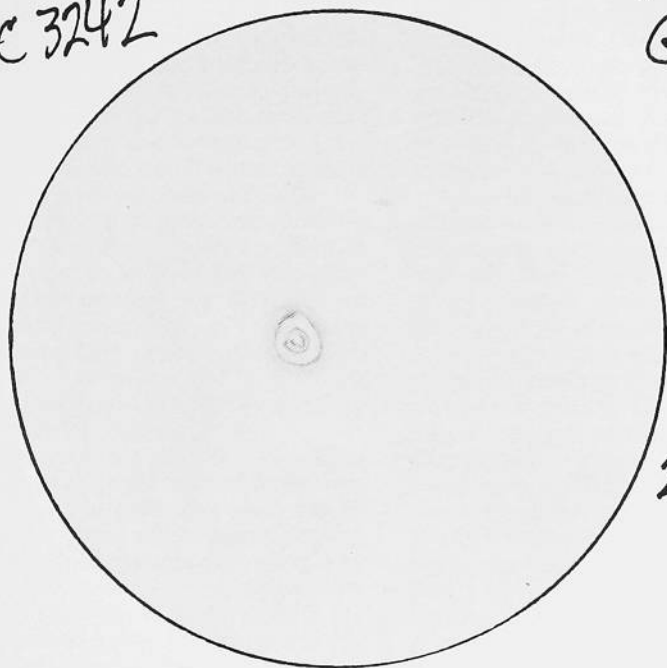
NGC 7662

190x



planetary in
Andromeda

NGC 3242



"Ghost of
Jupiter" -
what ring
detail!

254x

NGC 6826

The "Blowing
Planetary" in
Cygnus.



190x

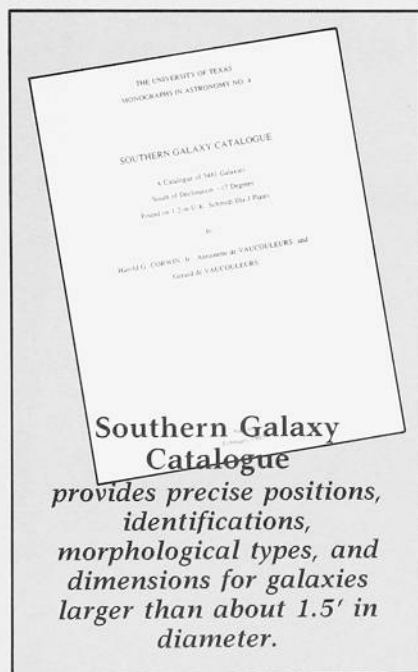
All sketches made with a 10-inch f/6 reflector.

DSM Reviews

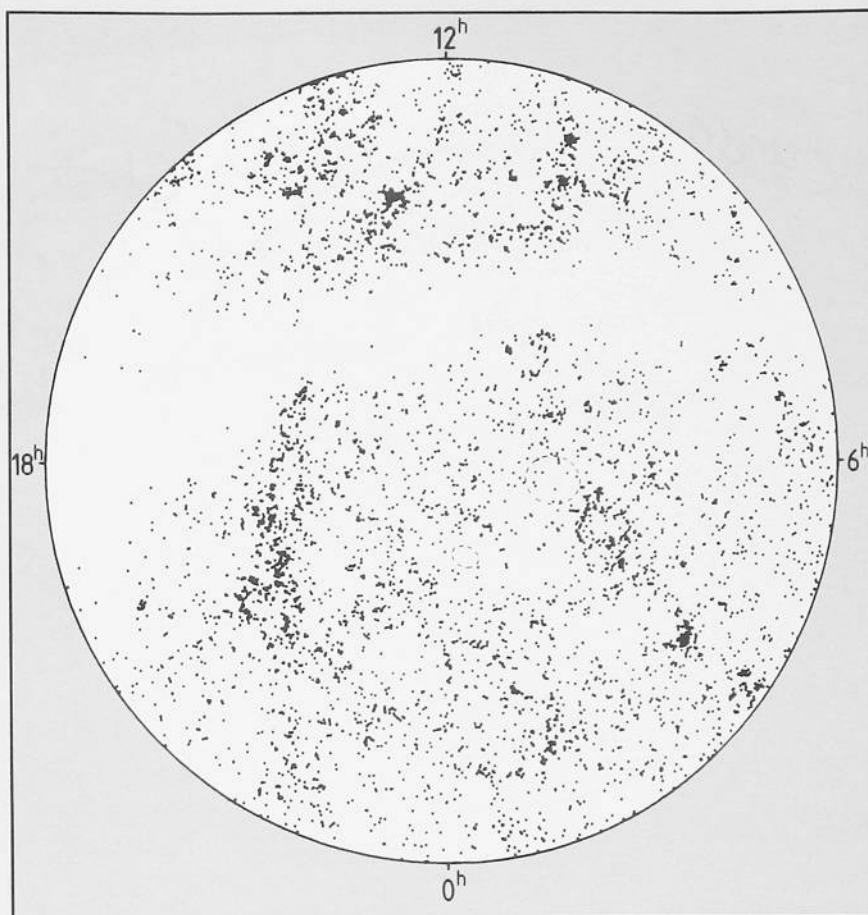
Southern Galaxy Catalogue, a catalogue of 5481 galaxies south of declination -17 degrees found on 1.2-meter U.K. Schmidt IIIa-J plates Harold G. Corwin, Antoinette de Vaucouleurs, and Gerard de Vaucouleurs, eds.
University of Texas Monographs in Astronomy No. 4 (1985)
\$14 Paper, xxxv + 308 pages, also available on magnetic tape

This catalogue serves as a basis for exploration of bright galaxies in the southern sky. It provides precise positions, identifications, morphological types, and dimensions for galaxies larger than about $1.5'$ in diameter.

The main purpose of this work was to



provide morphological types and angular dimensions on a uniform system for the upcoming *Third Reference Catalogue of Bright Galaxies* (RC3), to be produced by the same group of authors. The 606 U.K. Schmidt Southern Sky Survey plates or film copies were examined by hand using a magnifier for galaxies meeting the general criterion of being relatively large. In addition to providing type and dimensions, the extensive notes to the tabular list give detailed analytical descriptions for every galaxy. These include comments about dust lanes, bars, HII regions, interaction with neighboring galaxies, superposed stars, and so on. This information will be useful to visual observers, searchers for



This plot shows all 5481 galaxies in the SGC on a polar projection, with the south celestial pole at center. The Magellanic clouds appear as dashed ellipses. Courtesy Harold G. Corwin.

supernovae, and photographers.

Also helpful to amateur observers are the identifications. Corwin is perhaps the most authoritative source of NGC identifications: he has tracked down hundreds of errors and ambiguities in the famous catalogue, often referring to original sources to resolve problems. Many new NGC/IC identities are included here, some only in notes where, for instance, an NGC object near a galaxy has been found to correspond to a faint double star. References are also made to the ESO Catalogue (more properly, *ESO/Uppsala Survey of the ESO (B) Atlas*) by Andris Lauberts; indeed, most of the coordinates are taken directly from this work. The ESO Catalogue, based on plates taken with the 1-meter Schmidt at La Silla, Chile, includes clusters and nebulae as well as galaxies — 16,000 galaxies among a total of 18,500 objects.

The dimensions in the SGC are those measured directly on the Schmidt plates. Because they are of very high quality (better than Palomar Schmidt

plates), the visible extent of nebulous objects is extremely large. It extends roughly to the B magnitude 27.5 per square arcsecond isophote. Approximate relations are given to reduce these to the system of the RC2 (magnitude 25 per square arcsecond), but a more thorough analysis awaits the RC3, due for publication in 1987.

The catalogue includes no magnitudes, radial velocities, or other information. A new massive compilation of magnitudes is being completed by Lauberts and his collaborators, and we can expect to see those results in the RC3.

Copies of the SGC can be obtained by writing to: The Librarian, Peridier Library, Department of Astronomy, RLM 15.308, University of Texas, Austin, TX 78712-1083. The more comprehensive ESO Catalogue, by the way, is available postpaid for \$15 U.S. from: European Southern Observatory, Karl-Schwarzschild-Strasse 2, D-8046 Garching-bei-Munchen, FRG West Germany.
— Brian Skiff.

Double Stars

Double Doubles

by Glenn F. Chaple, Jr.

If you browse through a copy of *DSM* #1 (Winter 1982), you'll discover something weird about this column — weirder than usual, that is. The featured double stars belong to the constellation Lyra. What were summertime double stars doing in a winter issue of *DSM*?

Basically, things got out of sync when the old *Deep Sky Monthly* assumed its current identity as *Deep Sky* magazine. I was back on track with *DSM* #2, but I kept thinking about those poor misplaced Lyra doubles. Many of you may have forgotten to look them up when Lyra returned to the evening sky the following summer.

So to set things straight, I'm going to re-feature the Lyra doubles mentioned in *DSM* #1 — plus a few new ones so no one accuses me of recycling an old column. The theme of that article was "double doubles" — two similar-looking double stars placed side-by-side in the eyepiece field. As you might guess, my headliner was the "Double Double" — **Epsilon (ϵ) Lyrae**.

Don't attack this celestial masterpiece with your telescope until you've carefully studied it with the unaided eye. Most of us (me included) see a single 4th-magnitude star situated about a degree and half northeast of Vega. But if you're gifted with exceptionally keen vision, ϵ Lyrae appears as two tiny points of light almost in contact. Their actual separation is 3.5' (208"), close to the theoretical limit of resolution for the human eye. Let me know how your naked-eye resolution test goes.

There's no contest on this next double — binoculars and finderscopes

are ideal to comfortably separate ϵ^1 from ϵ^2 Lyrae for easy viewing.

But it's a telescope that weaves real magic on ϵ^1 and ϵ^2 Lyr, transforming each into a gleaming stellar pair — the famed "Double Double" that has captivated sky-watchers for over two centuries. I wonder how many times first-time viewers have aimed a telescope at this system, peered into the eyepiece, and gasped in astonishment?

A true heavenly masterpiece, ϵ Lyrae is a treasure that belongs to virtually anyone who owns a telescope. Even a modest 60mm refractor fitted with a 100x eyepiece shows the "Double Double" in all its splendor.

Let's shelve the superlatives for a moment and look at the basic statistics on this star system. The northernmost pair, ϵ^1 , consists of magnitude 5.1 and 6.0 stars separated by 2.6". The fainter component lies almost due north of the primary (position angle = 357°). This is a slow-moving binary whose period likely exceeds 11 centuries. ϵ^2 is also a binary but with half the period of its partner. The magnitude 5.4 secondary currently sits 2.3" east (p.a. = 94°) of the main star, which shines at magnitude 5.1.

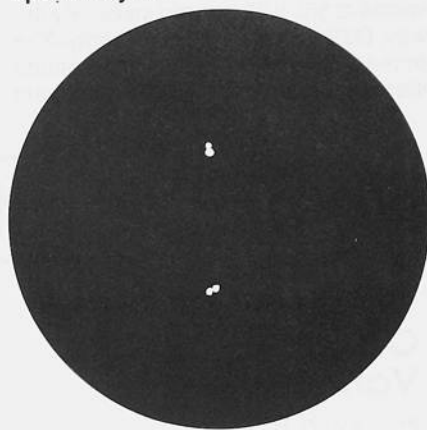
ϵ^1 and ϵ^2 have shown no relative motion; their waltz around a common center of gravity takes thousands of centuries. All four component stars display A-type spectra and appear white. The entire system is about 180 light-years distant.

If you own a small telescope, see if you can spot a 9th-magnitude star that forms a flat triangle with ϵ^1 and ϵ^2 . This faint pair was discovered by the English astronomers James South and John Herschel and bears the catalogue designation Shj 277.

A noteworthy, if less spectacular,

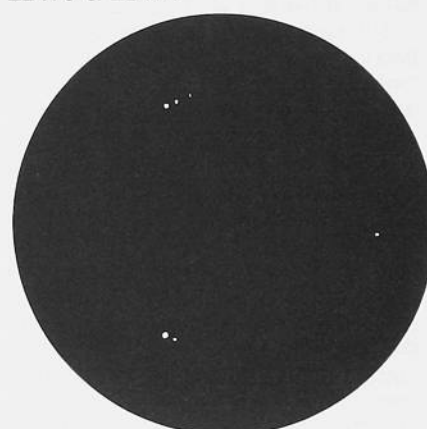
3-inch f/10 reflector
120x

Epsilon Lyrae



3-inch f/10 reflector
60x

$\Sigma 2470$ & $\Sigma 2474$



Sketches by Glenn F. Chaple, Jr.

Star	R.A.(2000)Dec.	Mags.	Sep.	P.A.	Year
ϵ Lyrae	18h44.3m +39°40'		147.1"	137°	1956
ϵ^1		5.1,6.0	2.6"	357°	1976
ϵ^2		5.2,5.5	2.3"	94°	1975
$\Sigma 2470$	19h08.8m +34°46'	6.6,8.6	13.4"	271°	1829
$\Sigma 2474$	19h09.1m +34°36'	6.7,8.8	16.2"	262°	1974
O Σ 366	19h14.2m +34°13'	7.7,10.3	21.8"	230°	1866
O Σ 367	19h14.5m +34°34'	7.1,9.6	34.4"	228°	1843

double double exists in eastern Lyra about a degree and a half south of ϵ Lyrae. The component pairs — $\Sigma 2470$ and $\Sigma 2474$ — are similar in magnitude, separation, and position angle, but the spectral types of the primaries are different: B for $\Sigma 2470$ and G for $\Sigma 2474$. These two double stars are separated by 10' and are not physically connected. The small-scope owner will find $\Sigma 2470$ and $\Sigma 2474$ much easier than ϵ Lyrae. Use a magnification of 50x.

John Bartels of Fairfield, California notes the presence of another brace of

double stars just 1° east of $\Sigma 2470$ and $\Sigma 2474$. The first member, **O Σ 366**, is an unequal pair at magnitudes 7 and 10 whose separation is 22" (p.a. = 230°). About 20' to the north is **O Σ 367**. This pair's magnitudes and position angle match those of **O Σ 366**, although its separation is 34".

John captured **O Σ 366** and **O Σ 367** with a 3¼-inch f/11 refractor; he also noted that the fainter components were visible at 55x with averted vision. By the way, **O Σ 367** has a multiple identity. The primary joins up with a 12th-magnitude star (21.5" separation, p.a. 74°) to form

Hough 648, while the secondary is a close pair (β 975: 9.7 and 9.8 magnitude, 1.3" separation, p.a. 244°).

If you're a stickler for details, you might reason that **O Σ 366** and **O Σ 367** aren't a bona fide double double. The separations don't match. There are innumerable instances where two dissimilar double stars appear close together. But true double doubles, like $\epsilon^{1,2}$ Lyrae and $\Sigma 2470/\Sigma 2474$, are celestial rarities.

* * *

DOUBLE TAKES: What are the 10 most popular double stars? When I

posed this question during the early days of *DSM*, I received about two dozen responses from a readership that numbered in the hundreds. Now that *Deep Sky* reaches over 15,000 amateur astronomers, I think it's high time to redo the survey. Send me a letter or postcard at the address below, listing your 10 favorite double or multiple stars. Include notes on your observing experience and the telescope aperture used. The tabulated results will appear in a future edition of this column.

82 South Harbor Road
Townsend, MA 01469

Variable Stars

Catch the Summer Variable Bug!

by David H. Levy

If you live optimistically, you measure the passage of your life not in years but in summers, the season when nature thrives in all its glory.

Summer! With its torrid temperatures and torrential rains but also some clear nights (I hope) that allow you to take advantage of the summer sky's cornucopia of variables. The short nights will keep you busy, for there is always something to view. Let's begin with the area surrounding the most prominent feature of the summer sky, the "Summer Triangle" of Vega, Deneb, and Altair.

Nearby is **SS Cygni**, an easily found dwarf nova whose bimonthly explosions have made it the most popular variable star of all. Even at minimum brightness, this star shines at a not-too-faint 12th magnitude and is even visible with a city-bound 8-inch telescope. The field is a little tricky to locate but once you succeed, it's easy to find. Learn its location well because you should watch **SS Cygni** every night (or several times a night if the star is going into outburst) if you want to catch its explosive act.

Another good star to begin your summer observing with is **Beta (β) Lyrae**, an eclipsing binary near Vega with a period of just under two weeks and night-to-night variations. The parallelogram of Lyra offers two stars that work well as comparison standards. Next you can move to Aquila, whose η Aqr provides a different type of eclipsing binary variation over a slightly longer period.

Three stars that are fun to find and observe lie in or near Hercules: **g Herculis**, **X Herc**, and **RR Coronae Borealis**. All are semi-regular variables that will provide an interesting weekly project for beginners and give them an idea of how this type of star acts.

With a telescope, turn next to Bootes. There **V Boo** goes through its leisurely 260-day period, from a maximum of 7.5 magnitude to a minimum of 10.7. Located only 1° northwest of 3rd-magnitude γ Bootis, this star is easy to find.

In late spring and early summer, turn your sights to Corona Borealis, the Northern Crown, for two unusual stars: **R CrB**, a reverse nova whose normal 6th-magnitude maximum occasionally vanishes as the star plummets eight magnitudes, and **T CrB**, a recurrent nova that has twice flared into prominence as an exploding star. We can also enjoy some of the Crown's

more traditional long-period variables such as **W CrB**, whose striking red color makes it easy to find.

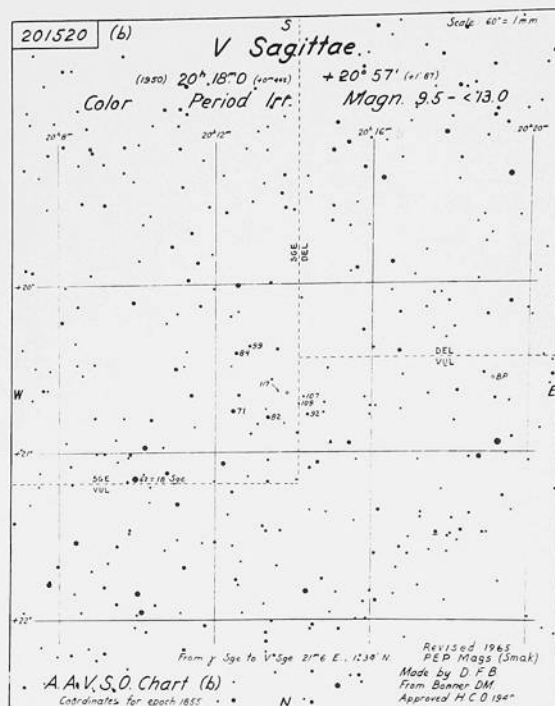
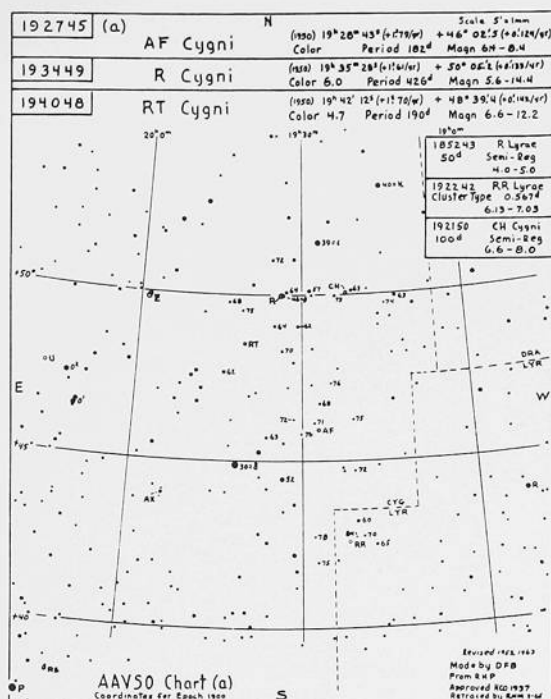
Cygnus the Swan offers so many variables that you could hardly begin to see them in a single summer. **R Cygni's** low-power field is especially pretty to watch, even more so when **R Cyg** is bright. And don't pass up **Z Cygni**, which also lies in a striking field. Cygnus' most famous variable is **Chi (χ) Cygni**, which is located in the middle of the Swan's neck. Although this star is often listed as a good beginner's star for new observers, I advise against trying for it unless you know that **Chi (χ) Cyg** is within three magnitudes of maximum — the field is so crowded with stars that you could spend half the night in frustration just trying to locate the variable.

The summer sky also contains **Sagittarius**, whose collection of over 2,500 variable stars hold something of interest for everyone. For example, try **RY Sgr**, a reverse nova similar to **R Coronae Borealis**. **RY Sgr** could fade at any time, so it's important to watch the field every night if you don't want to miss it.

In temperate latitudes, summer observing, with its many meteor showers, offers the year's finest sights for naked-eye observing. It also provides the most difficulty with mosquitoes, so remember to bring lots of insect repellent. But be careful what you touch — many plastics and enamel finishes on telescopes are attacked by the aromatic solvents found in most brands of bug goop. Welcome to summer.

154428 **R Coronae Borealis**. The mystery of **R Coronae Borealis** is surpassed only by the beauty of this star. Located in the middle of the Northern Crown, at maximum the star shines at about 6th magnitude and is barely discernible with a sharp unaided eye during a dark night. Through binoculars, **R CrB** lies near two fainter

AAVSO#	Name	Period	Type	Range
154428	R Coronae Borealis	irr.	R CrB	5.7-14.8
161138	W Coronae Borealis	238d	Mira	7.8-14.3
174406	RS Ophiuchi	irr.	nova	5.3-12.3
171014	α Herculis	irr.	semiregular	3-4
184205	R Scuti	140d	RV Tau	4.5-8.2
185243	R Lyrae	46.0d	semiregular	3.8-5.0
192150	CH Cygni	97d	Z And	6.4-8.7



stars — one at 7.2 magnitude, the other at 7.8. I have used the 7.2 star as a test for pristine dark-sky conditions; on dark Arizona nights, I can occasionally see it naked eye. To study R CrB seriously means observing it every clear night. The onset of its drop to minimum light is slow and teasing: the star can drop as low as 6.4 without necessarily "going the distance." If your first observations show R CrB at magnitude 6.2 or 6.3 and the next night you find it at 7.1, the chances are good that the star has begun a decline that will not end until you need a 12-inch telescope to see it.

154639 V Coronae Borealis. A long-period variable with a 3,581-day period and a magnitude range of 7.8 to 11.3. If constellation boundaries appeared in the sky as they are often shown on charts, this variable would be the easiest in the sky to find. It lies near the mutual boundary of three constellations: Corona Borealis, Bootes, and Hercules. The "V" stands for very red; in fact, this is one of the reddest stars in the entire sky.

161138 W Coronae Borealis. From 5th-magnitude Tau (τ) CrB, travel almost a degree-and-a-half northeast. There you'll find W CrB, a long-period variable with a period of 238 days and a magnitude of 8.3 to 13.0.

174406 RS Ophiuchi. This is a recurrent nova, a bit like LT Coronae Borealis except that it goes into outburst more frequently. The star's normal minimum brightness is magnitude 11.8 and its maximum ranges from 4.3 to about 6. Even at minimum, RS Ophiuchi changes by as much as a full magnitude. Find this star by searching about

2½° southwest of 4.6 magnitude Xi (ξ) Serpentis.

171014 Alpha Herculis. This bright star varies from 3rd to 4th magnitude with two superimposed periods: one lasts six years and the other extends from 50 to 130 days. Over a single summer, you might detect the shorter period's effects but will more likely see only slight variations in this interesting star.

163137 W Herculis. With a period of 280 days and a magnitude range of 8.2 to 13.5, this star is designed for those who dislike variables. Why? Because for each observation you get a bonus look at M13, one of the most magnificent globular clusters in the entire sky. Less than 2° west and 1° north of the cluster is W Herculis.

184205 R Scuti has been seen to range in brightness from 5.8 to 7.9 and shows many irregularities during its roughly 140-day period. Because the inspiring open cluster M11 is nearby, R Scuti is as easy to find as it is fun to estimate: the range is large, it is well placed in the sky, and it's a fine example of an easy-to-observe bright variable.

185243 R Lyrae. At first you might think this star perfect for beginners: its magnitude range of 4.0 to 5.0 and 50-day period seem ideal. But the chorus of problems encountered with bright semi-regulars echoes here and I caution observers to beware of bright red semi-regular stars with limited variation. This is a very red star, so also be careful of the Purkinje effect where the star seems to brighten before your eyes due to red light buildup on your retina. Use quick, sideways glances

rather than leisurely stares.

184134 RY Lyrae is a long-period star with a 9.6- to 14.4-magnitude range during a period of 327 days. The field can be found easily by sweeping a little more than 1° north and then 1° west of Beta (β) Lyrae. The star is easy to find if it is bright, but its faint minimum is hard to see without a 12-inch scope. A challenging star.

201520 V Sagittae. This star is a completely irregular variable and changes in small amounts almost nightly. It is somewhat difficult to find, however. Work from the 6th-magnitude star 18 Sagittae and the group of stars to its east and south. Since the patterns are not too obvious, finding V Sag may take some patience.

192150 CH Cygni. A "combination variable" in which members of both red and blue double star systems vary in brightness. T CrB also varies in this manner, as does Z Andromedae. During the mid-1960s, astronomer Armin Deutsch observed a new and previously undetected blue star spectrum that was added to the traditional red M6 spectrum that had seemed to identify this star.

CH Cyg is a bright red semiregular variable that performs admirably for viewers with binoculars or small telescopes. The star is easily found using binoculars and its 1.5-magnitude range from 6.6 to 8.0 is easily followed. CH Cyg's nominal period is 100 days, but its curve is not perfectly regular. Look for surprises with this interesting star.

Rt. 7, Box 414
Tucson, AZ 85747

Scanning the Literature

October 1985 —
March 1986

by Brian Skiff

In January 1982, Czech astronomer Lubos Kohoutek was observing the central star of the planetary nebula NGC 2346. Previous work had shown that this star was a spectroscopic binary, characterized by periodic shifts in its spectral lines that comprised a normal A5 V star (visible in amateur instruments) and a hot O-type subdwarf (the source of the radiation that fluoresces the nebula) orbiting with a 16-day period. Though the star was not previously known to be variable, Kohoutek found it was varying by perhaps two magnitudes with a period of about 16 days.

Since a binary was involved and the orbital period matched that of the variability, mutual eclipses of the system were presumed to cause the light variations. The eclipse became deeper and broader as time progressed, so that by early 1983 it occupied three-fourths of the 16-day cycle. It became clear that precession of the binary's orbit could not explain this evolution of the light curve, and the eclipse model was abandoned in favor of various schemes involving some kind of dust cloud.

While at MIT, the young astronomer Brad Schaefer examined the object on hundreds of plates stored in the Harvard College Observatory archives. He found the central star remained constant from at least 1899 until November 1981. By 20 December 1981 variations were evident on the plates — and were first noticed only a month later by Kohoutek.

Schaefer has now proposed a new model to explain variations in the star in "Mysterious Eclipses of the Central Star of NGC 2346" (*Astrophysical Journal Supplement Series* 297:245, 1 October 1985). Schaefer proposes that the O subdwarf has recently ejected a clumpy shell from its surface out of which dust has condensed. This is similar to the manner in which R Coronae Borealis stars are obscured intermittently by dense clouds formed when material is ejected from their outer layers.

As the dust shell expands in the binary system, it partly blocks the light of the brighter companion as it orbits the hot subdwarf. Like the R Cor Bor stars, Schaefer's model predicts that the mean brightness of the central star (now designated V651 Monocerotis) will recover and variations will cease as the dust continues to expand and dissipate.



Planetary nebula NGC 2346

Photoelectric observations from the Fall of 1984 showed a minimum near $V = 14.2$ and maximum near $V = 12.5$. Visual estimates from October 1985 appearing on AAVSO Circular 181 show a range from visual magnitude 10.6 to 12.8 — perhaps the skies are clearing around this binary! (By the way, this 12th-magnitude nebula is easy to see in a 6-inch telescope but is not plotted on the Tirion Atlas; 2000 coordinates are: 7h09m22.6s, $-0^{\circ}48'2''$.)

Speaking of positions, a list of positions for globular clusters has been published by Stephen J. Shawl and Raymond E. White in their article "Accurate Optical Positions for the Centers of Galactic Globular Clusters"

(*Astronomical Journal* (AJ) 91:312, February 1986). The listing gives precise positions accurate to about 1" for 109 clusters. You'd think this sort of information would be well known, but this list makes corrections to early positions for several objects, improving even on those compiled by Webbink in 1984. Users of *Sky Catalogue 2000.0*, volume 2, will be pleased to know that an early preprint of this paper was used in compiling the globular cluster section of the catalogue.

In *Deep Sky 10*, I reported on Heske and Wendker's study of the young cluster Trumpler 24 near Zeta (ζ) Scorpii. The authors then came to the unconventional conclusion that Tr 24



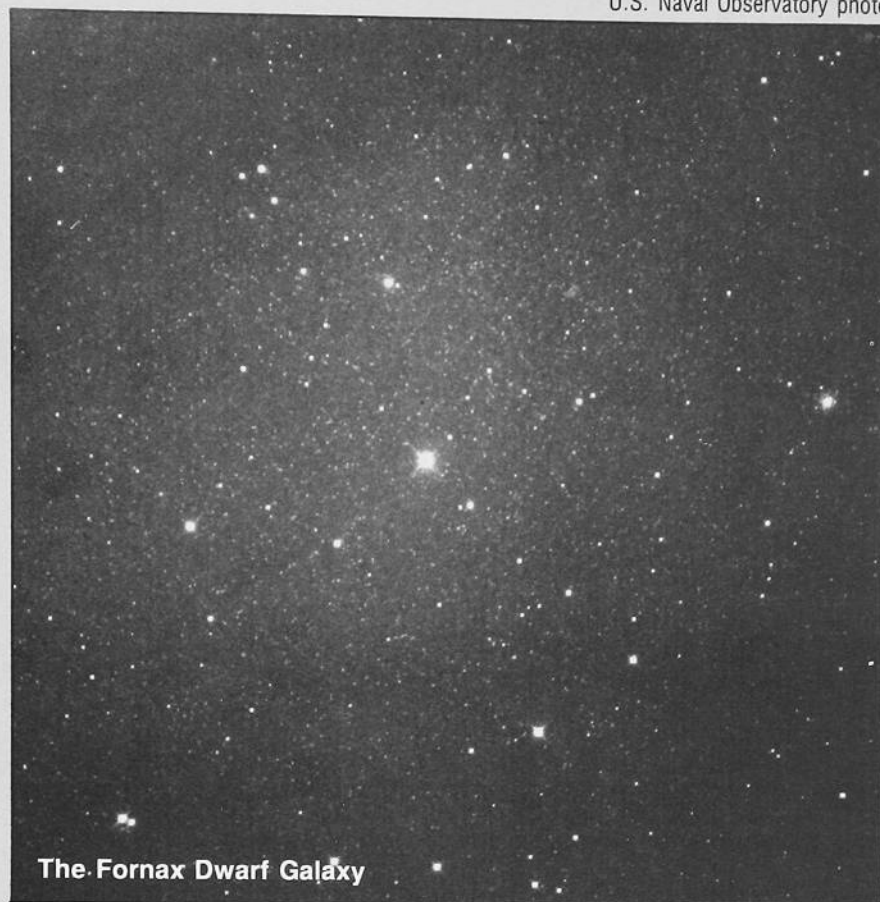
M35 (center) and its companion NGC 2158 (top right)

was the core of the Scorpius OB1 association and that the brilliant nearby cluster NGC 6231 was superposed in the foreground, i.e., not related to Sco OB1. They have now expanded their work, giving the results of a second year of observations in "Further Photometry and Spectroscopy in the Young Cluster Region Tr 24/Sco OB1" (*Astronomy & Astrophysics* 151:309). The authors give additional UBV photometry of stars in the region, particularly for candidate pre-main-sequence T Tauri stars in a concentrated group catalogued as Ruprecht 122. The new data support the team's earlier conclusions. Many of the T Tauri candidates do indeed show either variability or the spectral sig-

natures of extremely young stars. If confirmed by better data (the astronomers have been using rather small instruments for their work), these results would appear quite anomalous because all other known T Tauri complexes are embedded in dusty nebulae, whereas these stars are in the clear. Stay tuned.

A high-precision proper-motion study of Messier 35 has been completed by Bernard McNamara and Kazuhiro Sekiguchi, which they report on in "A Proper Motion Analysis of the Cluster M35" (*AJ* 91:557, March 1986). Their work involved a large number of plates taken between 1908 and 1984 with the Yerkes and Allegheny refractors. Relative proper motions and mem-

bership probabilities are given for 526 stars to V magnitude 14.7 and within a 14' radius of the cluster center. Dynamical studies by Robert Mattheu show that about two-thirds of the total population of the cluster lies within this radius, but this includes stars much fainter than the limit given here. The data provide an excellent separation of the cluster members from field stars, yielding 296 probable members in this area. There are now three possible red giant members (all about 8th magnitude), whereas none were identified prior to this work. Along with the table of data, which includes B and V photometry good to ± 0.04 magnitude, McNamara and Kazuhiro provide a



The Fornax Dwarf Galaxy

chart of the cluster.

A very different cluster lying in the same field as M35 has received new examination by a group led by Carol Christian and discussed in "The Open Cluster NGC 2158" (*Astrophysical Journal* 299:683, 15 December 1985). This is an important object because work by Arp and Cuffey 25 years ago showed it to be among the oldest known open clusters. The new work extends photometry of the cluster to magnitude 21, including stars well down the main sequence (in fact, intrinsically fainter than the Sun). The Christian group also obtained plenty of low resolution spectrophotometry for three cluster giants, which was used to estimate the age and metal abundance of the cluster. The astronomers find NGC 2158 to be slightly younger (three billion years old!)

and more metal-poor than NGC 2420, another well-studied old open cluster in Gemini, and similar to 47 Tucanae (NGC 104), a bright southern globular cluster known to be metal-rich among globulars. A distance of 3.5 kiloparsecs is estimated from the new photometry.

New photometry of globular clusters in a Local Group dwarf galaxy has been done by an Italian-Canadian-American group under B. Buonanno. Their findings are presented in the article "Color-Magnitude Diagrams for the Clusters and the Field of the Fornax Dwarf Spheroidal Galaxy" (*Astronomy & Astrophysics* 152:65). Color-magnitude diagrams to V magnitude 22 were constructed for the five globulars and two "field" samples from plates were taken with the 2.5-meter telescope at Las Campanas, Chile. The clusters

were found to resemble metal-poor globulars in the Milky Way, much as expected from current theories about galaxy formation. Yet the authors indicate that existing observations suggest "a complex history of nucleosynthesis that began at roughly the same time as the formation of the Milky Way Galaxy's halo and has continued . . . until a few billions of years ago." The distance of the Fornax dwarf determined here is 130 kiloparsecs, no farther than the most distant galactic globulars. The absolute magnitude is thus -12.3, about one magnitude brighter than the similar Sculptor dwarf but three or four magnitudes fainter than the Andromeda group dwarfs NGC 147 and NGC 185.

While the Fornax galaxy has too low a surface brightness to spot in amateur telescopes, the cluster members are not at all difficult — one of them even has an NGC number! Positions and total V magnitudes are listed in the table.

One of the Hubble Space Telescope's (HST) first tasks will be to attempt to observe individual Cepheid variables in the Virgo cluster. These will help establish the distance to the cluster (and hopefully, the Hubble constant) more accurately than presently known. An observing list of galaxies for Earth-bound astronomers to start working on before the instrument flies is provided by Allan Sandage and John Bedke in "Candidate Galaxies for Study of the Local Velocity Field and Distance Scale Using Space Telescope. I. The Most Easily Resolved. II. The More Difficult Cases. III. Galaxies in the Virgo Cluster Core" (*AJ* 90:1992-2008, October 1985). The three-part article describes over 300 galaxies that promise resolution into individual stars with the HST. Precise coordinates and fabulous photographs are given for each. A few of the closest galaxies in the list can be (and have been!) resolved from the ground into the most luminous red and blue supergiants and Cepheids. But with the HST, the authors feel we will probably see only the most luminous supergiants, although Cepheids at blue magnitude 25 or so may be resolvable with some difficulty.

One of these easily-resolved galaxies is NGC 2403 in Camelopardalis. A catalogue of stellar associations in the galaxy has been compiled by Paul Hodge in "Stellar Associations in the Galaxy NGC 2403" (*Publications of the Astronomical Society of the Pacific* 97:1065, November 1985). This paper includes a detailed photograph of 88 features in NGC 2403. Among the features shown are stellar associations which appear similar in size and content to those in M33 and the Large Magellanic Cloud.

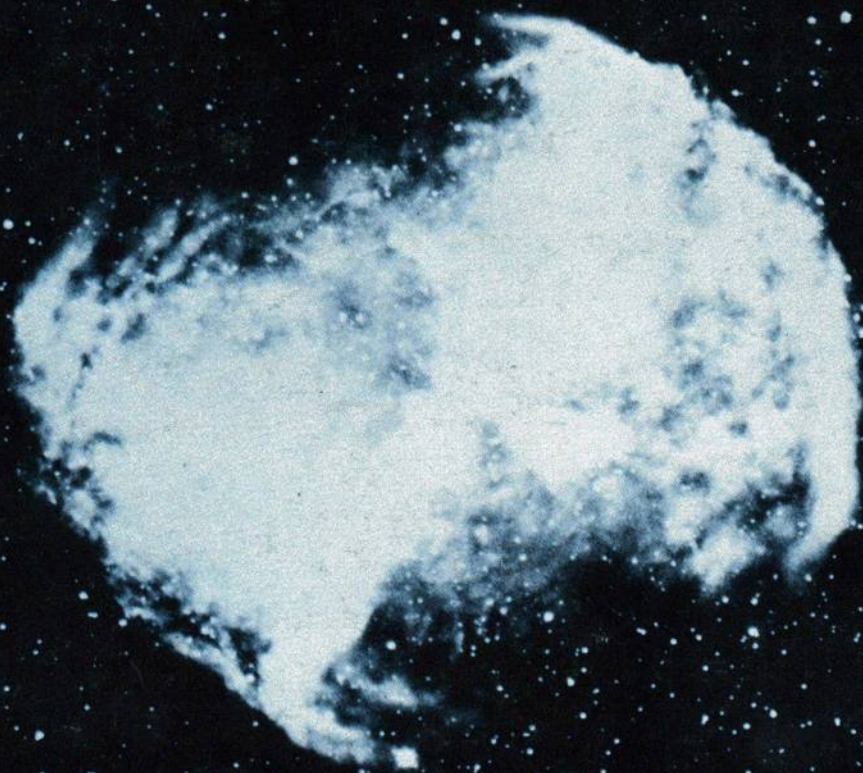
421 West Aspen
Flagstaff, AZ 86001

Name	R.A. (2000) Dec.	V.
1	2h37.02m -34°11.1'	15.6
2	2h38.44m -34°48.1'	13.5
3	2h39.49m -34°15.5'	12.6 (= NGC 1049)
4	2h40.09m -34°32.4'	13.6
5	2h42.21m -34°06.2'	13.4

Source: R. Webbink, in *The Dynamics of Star Clusters*, Reidel (1985).

Ring-shaped planetaries are many amateurs' favorites. Top left: M57, the Ring Nebula in Lyra. Photo by Leo C. Henzl, Jr. Below: The egg-shaped NGC 6563 in Sagittarius. Photo by Jack B. Marling. Bottom: The largest planetary in the sky, the Helical Nebula in Aquarius. Photo by Paul Roques. Bottom left: NGC 6369 in Ophiuchus appears as a perfectly circular ring in small telescopes. Photo by Jack B. Marling.





The Dumbbell Nebula in Vulpecula
National Optical Astronomy Observatories photo